MINUTES OF PROCEEDINGS

OF

THE INSTITUTION

OF

CIVIL ENGINEERS;

WITH OTHER

SELECTED AND ABSTRACTED PAPERS.

VOL. LIX.

EDITED BY

JAMES FORREST, ASSOC. INST. C.E., SECRETARY.

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ERRATA.

Vol. lii., p. 68, line 4 from bottom, *for* "21" *read* "53."
Vol. lv., p. 130, line 1, *for* "D. P." *read* "G. J."
" p. 134, " 11 from bottom, *for* "126°" *read* "125°."
Vol. lvi., p. 99, last line, *for* "35" *read* "125."
" p. 296, line 5, *for* "Scott" *read* "Dr. Schott."
" p. 298, " 13, *for* "14*s*. 6*d*. per *ton*" *read* "14*s*. 6*d*. per *cask*."
" p. 373, " 18, *for* "evaporation" *read* "composition."
Vol. lvii., p. 194. In reference to Mr. Brebner's remarks through the Secretary, Mr. Chance desires to direct attention, in reply, to observations on pages 119 and 175.
" p. 373, line 9, *for* "fourth root" *read* "one-fourth root."
" p. 374, heading of table, third column, *for* "mètres per *sct*" *read* "mètres per *sec*."
Vol. lix., Plate 10, Fig. 3, *for* horizontal scale "1 in 400,000" *read* "1 in 500,000."
" " *for* vertical scale "1 in 400" *read* "1 in 500."

THE

INSTITUTION

OF

CIVIL ENGINEERS.

SESSION 1879-80.—PART I.

SECT. I.—MINUTES OF PROCEEDINGS.

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11 November, 1879.

WILLIAM HENRY BARLOW, F.R.S., Vice-President, in the Chair.

The following Associates have been transferred by the Council to the class of

Members.

JOHN PHILIP CORTLANDT ANDERSON.
THOMAS ALFRED BULKLEY.
ROBERT CRAWFORD, M.A.
JOHN JACKSON.
JOHN TOWLERTON LEATHER.
ROBERT KNOX MACBRIDE.
GEORGE EDWARD ORMISTON.
GEORGE PALMER.
FRANCIS FREDERICK SMITH.
JOHN TATE.
FREDERICK ROBERT UPCOTT.
ALFRED FERNANDEZ YARROW.

The following Candidates have been admitted by the Council as

Students.

THOMAS ADAMS.
HERBERT WILLIAM ANDERSON.
JOHN THOMAS PRICHARD BASSETT.
EDWARD STANLEY BAYLIS.
HENRY CURREY BOWDAGE.
THEOBALD BUTLER.
ALBERT HAVELOCK CASE.
JOHN ARTHUR DOCKRAY.
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JOSEPH WILLIAM FELLS.
PERCY MURLY GOTTO.
PHILIP HAMMOND.
WALTER TWINING HOLBERTON.
JOHN HENRY HOLMES.
CHARLES CRESSY HORSLEY.
ANDREW JOHN HUDLESTON.
HENRY JOSEPH JOHNSTON.
PERCY EDWARD KEENE.
WILLIAM KISSACK.
JOHN BAGOT LABATT.
ISAAC ARTHUR LEWIN.
ROBERT MCARTHUR.
WELLWOOD MAXWELL.
CHARLES THACKWELL MERRICK.
GEORGE EDMUND NEWTON PAULING.
HENRY ROCHE.
ROBERT BRUCE RUTHERFORD.
WILFRID THEODORE SKAIFE.
JOHN RICHMOND SMITH.
PHILIP SMITH.
JOHN STANDFIELD BRUNEL TARBOTTON.
FELIX ALEXANDRE TARGET.
GEORGE REAVELY TYNDALL.
LAWRENCE AUBREY WALLACE.

Discussion.

The discussion upon Mr. Blandy's Paper on "Dock Gates,"[1] which was read at the concluding meeting of the last session, was then taken.

Mr. Phipps. Mr. G. H. PHIPPS observed that, without going at length into all the details of the Paper, he would express a general concurrence with the methods given for calculating the strains at various points of Dock Gates. They were the same as he had adopted and explained in the discussion of Mr. Hayter's Paper on the Charing Cross Bridge in 1863.[2] The business of all these calculations was to determine the increase of strain either in arched structures or on straight beams, whenever the line of pressure or curve of equilibrium travelled along any other line than that of the neutral axis. Agreeing, therefore, with the Author upon the above portion of the Paper, he nevertheless regretted the absence of any opinion upon several matters connected with Dock Gates of great interest to practical men. These points were chiefly two in number: the relative advantages of wood and of iron for these gates; and the propriety or otherwise of doing away with the bearing roller, usually fixed near the outer end of Dock Gates in this country. On the first of the above heads a general feeling seemed to exist amongst engineers in favour of wood, on the ground that wooden gates were often quite as cheap, and sometimes cheaper than iron gates; that they were equally, if not more, durable; and that wood, arising probably from its more yielding character than iron, permitted the gate to accommodate itself better to the sill, and, when bearing rollers were employed, to adjust itself better to any slight irregularities in the roller path. One of the advantages claimed for iron gates was the buoyancy capable of being given to them by water-tight compartments. It had been urged that this could not be reckoned upon in practice, from the difficulty of keeping the gates water-tight. He thought, however, that this objection was untenable under the excellent workmanship of the present day. As to bearing rollers, strong opinions against their use had been expressed by Sir John Hawkshaw and Mr. Hayter; whilst the opposite view was entertained by Sir W. Armstrong, Mr. Brunlees, Mr. Abernethy, and Mr. Duckham.[3] Sir John Hawkshaw argued that bearing rollers were unnecessary, as shown by the universal practice in Holland; but Sir W. Armstrong and other engineers considered that without rollers, far too great a weight, with con-

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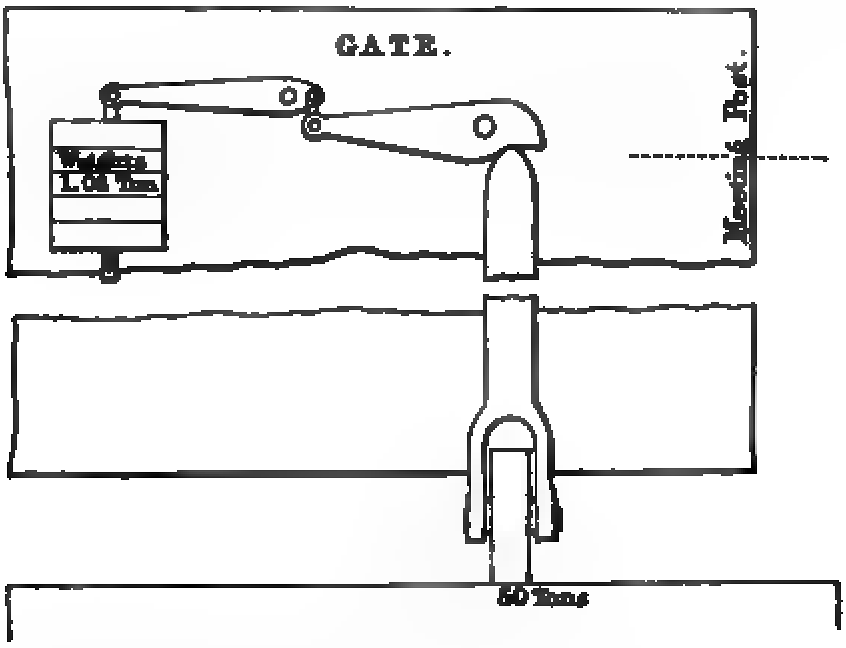
[1] *Vide* Minutes of Proceedings Inst. C.E., vol. lviii., p. 154.
[2] *Ibid.*, vol. xxii., p. 537.
[3] *Ibid.*, vol. l., p. 90 *et seq.*, and vol. lv., p. 13 *et seq.*

sequent wear and friction, would be thrown upon the heel-pivot and anchorage. Now it appeared to him that the use of rollers ought to depend upon the firm and permanent character of the roller path; for if this was at all out of the correct position of its plane at right angles to the hollow quoin, it was obvious that it might give rise to a tremendous strain on the roller and path. But even if the plane were kept quite true, mechanical experience proved how impossible it was with a rigid roller to properly apportion the strain on the heel-post and anchor to that upon the roller. In order to meet this difficulty, he would adopt an arrangement of levers, as represented in Fig. 1, whereby any Mr. Phipps.

Fig. 1.



required pressure might be brought upon the roller, which would enable the latter to rise and fall on the occurrence of irregularities or obstructions in the roller-path.

In the Avonmouth Dock[1] the weight of a single gate was given as 102 tons, which, equally divided between the heel-pivot and roller, would give 51 tons on the latter, without deduction for buoyancy. This, with the proportion of levers represented, namely 49 to 1, would require the application of a weight just exceeding 1 ton.

Mr. H. Hayter said an arrangement, not unlike that mentioned by Mr. Phipps, had been introduced in the dock gates of the Elizabeth Dock at Maryport by the late Mr. Rendel, but it did not answer in practice. Such a contrivance would seldom be brought into operation, and the joints would not be kept oiled; and although ingenious, he thought the contrivance was somewhat too elaborate for practical application in Dock Gates. There was Mr. Hayter.

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. lv., p. 13.

Mr. Hayter. probably not much room for discussion on the theoretical part of the Paper; but there was in regard to its practical aspect. The Author had stated that the most economical form of gate was that in which the rise was equal to a third of the span, and that was perhaps true. He had also stated that the most economical was not necessarily the most advisable form for a pair of dock gates, and that a convenient form for small, or medium-sized gates, was that in which the rise equalled a sixth of the span. Dock Gates in England were generally made in accordance with that view. In Holland they were, as a rule, flatter; but there the differential head was small. He agreed with the Author that the best, or at any rate a very suitable form of gate was that in which the rise was equal to about a sixth of the span. If one-third of the span the construction became inconvenient, and the recesses too deep, entailing practical difficulty in working. The Author had further stated that the faces of the gates, when open, should be in line with the side wall of the entrance. He had found it better to set the gates back at least 1 foot from the line of the wall, so that they might be well-housed and protected from injury. With that exception he agreed with the Author's conclusions both theoretical, as far as he had studied them, and practical.

With reference to the comparative merits of wood and of iron in the construction of Dock Gates, Mr. Hayter could not quite agree with Mr. Phipps. He had erected many gates both of iron and of wood. Iron gates had to be constructed as caissons, and it was difficult to keep caissons subjected to rough usage water-tight; and it was, moreover, difficult accurately to fit and adjust wrought-iron gates. Wooden gates, at any rate if made of greenheart, lasted as long, or longer, than iron gates, especially near the sea, where the sea-water and exhalations from the sea so rapidly deteriorated both wrought and cast iron, especially the former. Moreover, wooden gates were less costly to construct and to maintain; and on the whole he thought they were better than iron. He had gone into this aspect of the question in the discussion on the dock at Avonmouth and the dock at Whitehaven,[1] and he would not repeat what he then said. On that occasion he had also alluded to the abandonment of rollers in Dock Gates, to which he would again briefly refer. In England rollers were generally used in gates, unless they were small in size. Abroad, at any rate in Holland, they had almost universally been abandoned, and there was no doubt a considerable advantage in doing without them. As a rule, Dock Gates without rollers were manipulated

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. lv., p. 71.

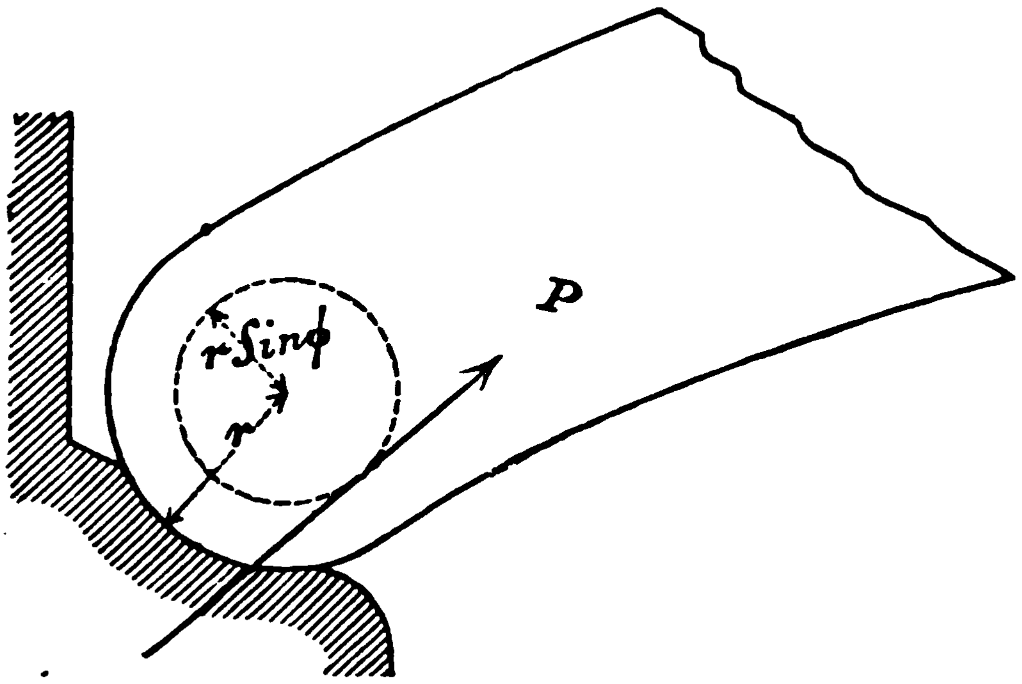
Mr. Hayter.

with greater facility. With reference to the question of cost, he had found that by abandoning rollers there was a saving of between £400 and £500 in the cost of a pair of gates in a lock about 60 feet wide, taking into account that the roller, the spindle, the adjusting apparatus, the roller path, and the elaborate masonry to receive it were then unnecessary. Obstructions sometimes occurred on the roller path, and it became necessary occasionally to send down a diver to remove them. A diver could not always be had; and where the water was shut back by one pair of gates, it was evident that if they could not be closed, the water would get out of the dock, and much damage might accrue to the shipping. Practically gates were generally strong enough to do without rollers. The anchor was always of excessive strength and also the pivot, and the gates as a rule were very strong. Sometimes in erecting gates before the roller was attached, and before the gates were supported by water, they were allowed to swing to and fro. This he had noticed, and yet he had never heard that they had sustained injury. There were, however, some exceptional cases where rollers ought perhaps not to be dispensed with. Thus in the case of gates of large size, say in a lock 100 feet wide, rollers and roller-paths ought perhaps to be introduced. It was generally the practice to adopt two rollers in such a case in each leaf. He thought that one roller would be sufficient. Further, there had lately been put up at Dover, gates which were sometimes subjected to the pressure of a wave of 3 feet on the concave side at high tide. In that case the rollers had steadied the gates. In addition a locking apparatus had been introduced, consisting simply of an eye riveted to the leaf of each gate, into which, when the gates were together, a strong bolt or pin was inserted. One such contrivance was placed at the top of the gate and another about 6 feet down. By these means the gates were enabled to withstand the pressure of a wave of 2 or 3 feet without movement. Before this contrivance was adopted the gates were held tight by the chains that closed them, and for that purpose the crabs had to be made very strong. Since the introduction of the locking apparatus, the chains had not been used to hold the gates when at high water there was a sea disturbance. He would not further allude to the subject, inasmuch as the Institution had accepted from him a Paper on the Amsterdam canal, in which there were some thirty or forty pairs of gates. These presented features of interest to which he should have to call the special attention of the members when that Paper was read.

Prof. Unwin. Professor W. C. Unwin remarked that others were more competent than himself to deal with the practical details of the Paper; but he might be permitted to make one or two remarks on some of the theoretical points contained in it. It would be obvious that the question of the strength of the parts of a lock gate was one of considerable complexity, and that in fact theory was incapable of dealing exactly with the conditions of such a problem. Certain approximate assumptions, therefore, had to be made as to the conditions in which the gate was, and the only fair criticism on the theory of such a thing as a lock gate was that which dealt with the question, whether the assumptions were fairly approximate ones, or the best that could be made. He thought the Author had shown that he had fully considered the conditions of the problem, and that on the whole he had fairly treated it from the most approximate point of view which was possible. He had practically drawn for lock gates what engineers would recognise as the well known line of pressure, which appeared in most treatises of applied mechanics, but which he was sorry to find he had called by a new name. He thought it would be convenient to keep to recognised names for recognised curves. To call the line of pressure the line of position of resultants was almost as if a new name had been invented for the circle or the parabola. In using the line of pressures from which to determine the stresses, one assumption was at once made, namely, that no great deformation of the gate occurred from its constructed dimensions, that the pressures did not greatly alter the form of the gate; and on the whole he should think that for such a problem as a lock gate that was a fair assumption, because at best any solution of the problem must be an approximate one. The Author had adopted one method, which seemed to him perfectly right. Instead of fixing upon a particular line of pressures for the lock gate, he had found two limits within which the lines of pressure must lie, according as the pinch of the gate occurred at the up-stream or the down-stream edge of the mitre sill, and he calculated the gates on those two extreme assumptions, and took the worst stresses occurring in either of those cases. That was a rational way of dealing with a problem which could not be exactly solved,—to fix the limits within which the stresses must lie. In determining the position of the lines of pressure, however, he made one assumption, possibly inaccurate. He had assumed that the line of pressure passed through the centre of the heel-post. Now in shutting, the gate came in contact with the hollow quoin; and if it were supposed that after the gate was just closed and pressure was

upon it, there was an almost infinitesimal movement of the hard wood of the heel-post against the still more rigid stone of the hollow quoin, then a considerable moment of friction would be induced at the heel-post, and the line of pressures, instead of passing through the centre of the heel-post, would deviate from it. To neglect that possible deviation, while taking account of the deviation at the mitre-post, could only be justified if it was difficult to take account of it, or if the amount of deviation were small. It was not difficult to take account of the greatest possible friction at the heel-post, and the moment of friction might be considerable. Let r be the radius of the heel-post, ϕ the angle of repose of wood on masonry. At the centre of the heel-post let a circle be drawn with a radius $= r \sin \phi$. Then when friction was taken into account, the line of pressure would be a tangent to this circle. Fig. 2 showed the thrust P at the heel-post touching a circle having a radius $= r \sin \phi$. After using a great deal of applied Prof. Unwi

FIG. 2.



mechanics to determine the exact stresses in the different parts of lock gates, it appeared to him that the Author had abandoned applied mechanics in using the results, because he stated that instead of proportioning the gate so that the maximum stress should not exceed a certain limit, he proposed that the average stress should not exceed a certain limit. Instead of dealing with the greatest stress, he dealt only with the average on the whole section of the wooden beams. The reasons given for that did not appear to justify the course adopted. The Author stated that in crushing posts and so on, what was obtained was not the maximum stress on the section, but the average stress. That was true; but in those experiments the greatest possible care had been taken, if they had been made rightly, that the average stress should not widely differ from the maximum stress, whereas in lock gates the

Prof. Unwin. average stress might differ in almost any degree from the maximum stress. It appeared, therefore, to him that it was to abandon applied mechanics altogether, if, after going through those laborious calculations, a limit was merely fixed to the average stress on the sections of the beams of a lock gate. The Author was right in saying that experiments with small specimens were bad guides in determining what the maximum stress in such a gate should be. Experiments with small specimens might be misleading, and there were possibly no good data for determining what the maximum stress ought to be; but the proper way of determining it would be, to apply those calculations to a number of gates which had actually stood, and to find what maximum stress had been safely borne. If a gate were found in which the wood carried, say, 1,000 lbs. to the square inch as a maximum stress, another gate might safely be built with the same limit, and it would be sure to stand also. He alluded to that subject, because it appeared to him to be one of capital importance in dealing with the question of the strength of materials. He thought if the Author had had less practical experience with lock gates, and more with the handling of formulæ, he might have simplified that portion of the Paper which related to iron gates, and Professor Unwin might possibly be able to suggest to him a simplification of the way in which he had treated the stresses.

Mr. Browne. Mr. W. R. Browne wished it had been stated more clearly by the Author in what relation his Paper was to be taken as standing to previous investigations. In his own communication on the same subject, read before the Institution in 1870,[1] he had mentioned the two earlier papers of Mr. Peter Barlow[2] and of Mr. Kingsbury.[3] Again in June, 1873, "The Engineer" contained a series of articles on lock gates, founded on a memoir by M. de Périssé,[4] giving a great deal of information derived from similar inquiries, both abroad and in this country. He thought the Author should have shown in what respect the previous investigations were useless, untrustworthy, and imperfect, and how far his method was intended to supplement them. The practice of not referring to the existing literature on any subject was rather common in engineering matters; but it led to a great deal of confusion, making it difficult for any one to take up the subject afterwards, to follow its history, and to see what had really been done.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxi., p. 317.
[2] *Vide* Transactions Inst. C.E., vol. i., p. 67.
[3] *Vide* Minutes of Proceedings Inst. C.E., vol. xviii., p. 445.
[4] *Vide* Mémoires de la Société des Ingénieurs Civils, 1872, p. 319.

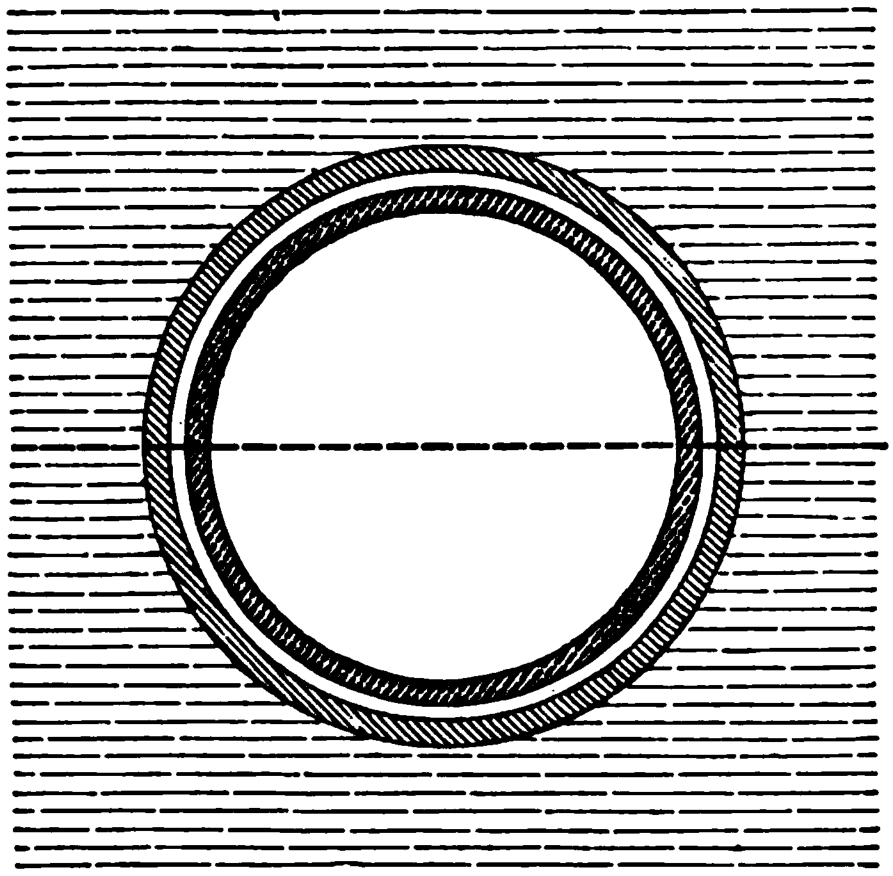
There were two points to which he desired to allude. In Mr. Blandy's treatment of the centre of pressure of the mitre-post, speaking of the mutual action of the gates on each other, he said: "The gates may be constructed so that, when under pressure, the meeting faces of the mitre-posts bear fair and true against each other, and distribute the mutual reactions uniformly throughout the width of the meeting faces. This is the normal condition of things."[1] He did not suppose that the Author meant to say (though the sentence looked as if he did) that whenever there were two surfaces so constructed as to bear fair and true against each other, it followed that the mutual reactions between those surfaces must be uniform; and consequently that the centre of pressure between those surfaces must coincide with the centre of the figure. He need not point out that the case of the voussoirs of an ordinary masonry arch was one where it was always assumed that the surfaces were perfectly bedded together, but where the whole problem was to determine how far the centre of pressure varied from the centre of the figure; and his own impression was that it was not, and could not be, the normal condition of things, that the pressures should be the same throughout the face of a pair of mitre-posts. In his Paper that question had been discussed, and he had assumed that the pressure varied from nothing at the outside, next the water, to a maximum on the inside of a mitre-post. That might or might not be a good assumption; but he thought it was at least better than to suggest, as the normal condition of things, that two gates when under strain had the pressure uniformly distributed over the surface of the mitre-posts.

The second point followed from an observation with regard to the best rise for dock gates. The Author stated: "Mr. Bramwell has pointed out that the most economical form of gate is that in which a pair of gates, when shut, form a continuous arc, subtending an angle of 133° 56'."[2] This referred to remarks made by Mr. Bramwell, in which that result had been given,[3] founded, however, upon a principle which Mr. Browne had laid down, that the best form for a pair of lock gates, under all circumstances, was one in which they made, when closed, the exact half of a circle. In his Paper, and subsequently in the discussion, he had stated that he did not agree with that as a general principle; but the reasons then given had not, he believed, been fully accepted

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. lviii., p. 158.
[2] *Ibid.*, p. 202. [3] *Ibid.*, vol. xxxi., p. 341.

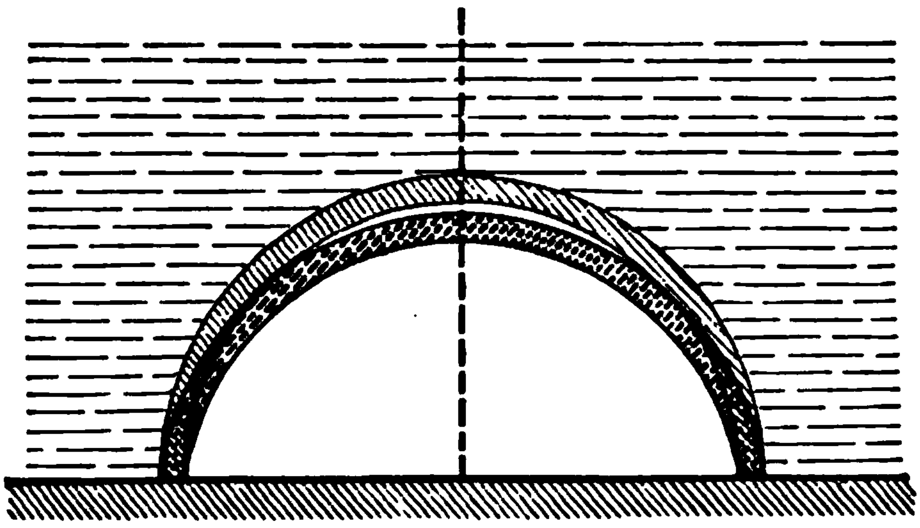
r. Browne. as sufficient; and he hoped the members would pardon him for returning to that point. Mr. Bramwell illustrated his view by two diagrams, which were practically reproduced in Figs. 3 and 4. His argument was simply this: Suppose a cofferdam or cylinder to be built in the form of a circle to resist water-pressure (Fig. 3),

Fig. 3.



then, as the pressure upon every point would be the same, he asked, how would the circumstances be altered if the circle were cut in two, and either half, instead of bearing against the corresponding half, bore against a wall, as in Fig. 4? He further asked, How would

Fig. 4.



it be altered if it were cut again in the middle? And so he went on by a succession of easy steps to the ordinary case of a pair of lock gates. To this argument his own reply would be that, as far as concerned the closed cofferdam, he agreed that the circular form would be the right one. And he would point out that, supposing the cofferdam to be compressed by the water, it would take a form still that of a circle, but of a smaller circle, such as

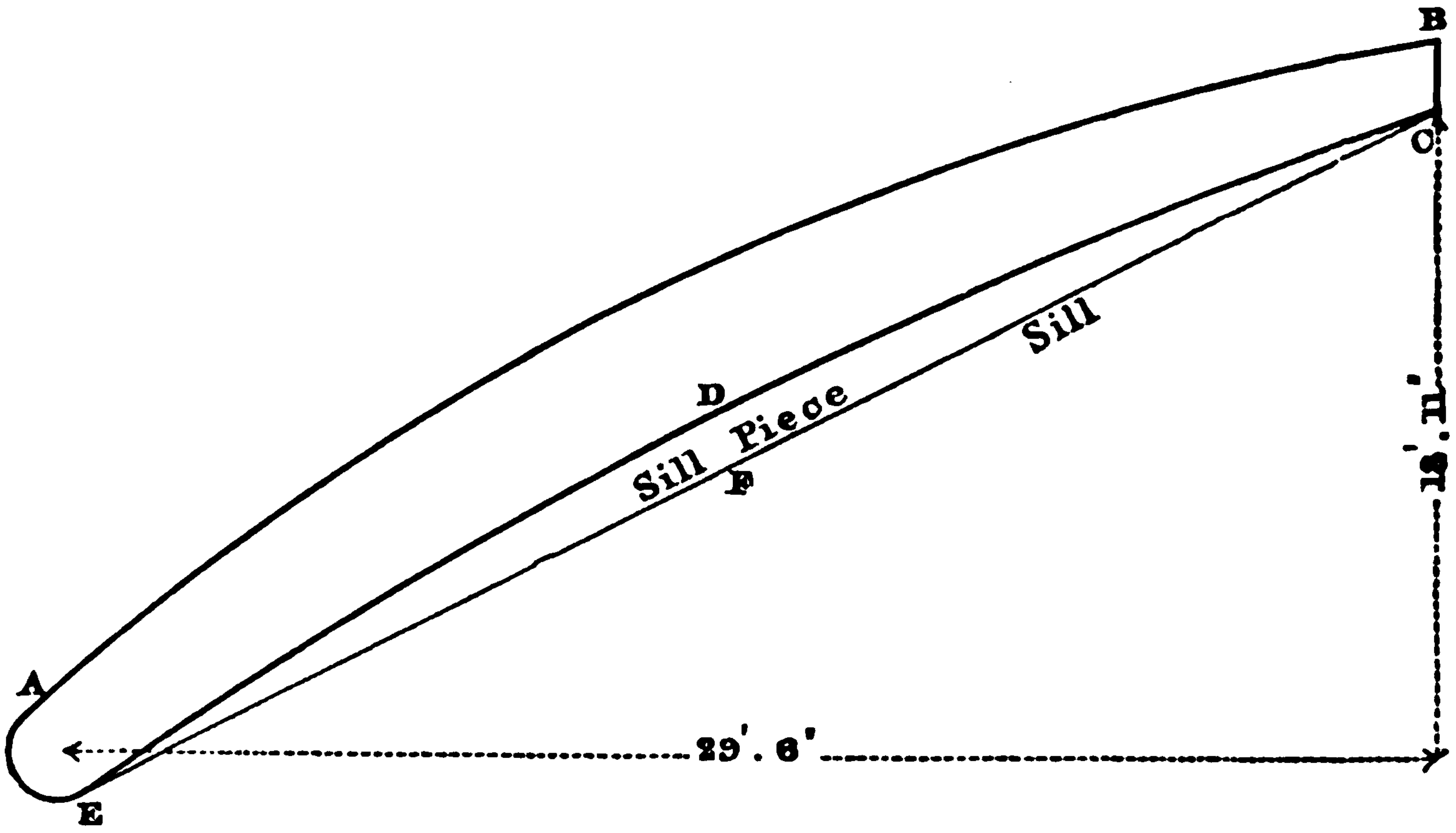
was shown by the dotted lines in Fig. 3, where, of course, the compression was enormously exaggerated for the sake of clearness. But when Mr. Bramwell said, "Would not the same follow if a gate were made semicircular?" he should reply, he could not answer that question until he knew the nature of the construction at the two ends of that semicircle, and where it abutted upon the wall. If the construction was that of a pair of lock gates, he should say that Mr. Bramwell's conclusion did not follow, because in that case the end abutting against the wall would become an ordinary heel-post fitting into a hollow quoin, and confined at the top and bottom by the collar and pivot respectively; and consequently, when a pressure came upon that semicircle it could not take the form of a smaller semicircle such as would be the half of the dotted circle in Fig. 3, because the abutments could not move. It would take some form such as the dotted curve shown in Fig. 4; and all that could be said of that curve was that the two halves must be symmetrical with each other; it could not be said that either of the halves would be the arc of a circle, or that, if they were, they would be arcs of the same circle. All that must be matter of calculation; and the argument derived from symmetry at once ceased to be applicable. Therefore, without going into the question of what was theoretically the most economical value of the rise, what he submitted was this: that it could not be said off-hand that, whatever the rise might be, the cylindrical form of a pair of lock gates was always the best; it was a question to be decided by calculation in each case. Mr. Browne.

With reference to the question which had been raised as to the use of rollers, he might mention one fact. He was present, ten years ago, at the taking out of the wooden gates of the old north lock at the Bristol dock entrance. When one of those gates, which had been in use for many years, was removed, it was found that, through some maladjustment at the time when the gate was set to work, or at any rate the last time the gate had been removed, the roller had never borne upon the roller path, but was about $\frac{1}{4}$ inch off it. No difficulty had been experienced in working that gate; and the fact would not have been known to the present day had not the lock been destroyed and the gate taken away. The span of that lock was not large—about 35 or 40 feet—but it was not an excessively small span; and the rise and fall of tide was over 30 feet, so that the gate was by no means a light structure. That fact went to show that an ordinary wooden gate intended to work with a roller, and constructed with that view, could be worked without a roller for many years

owne. without any one knowing it. This appeared to confirm strongly the view expressed by Mr. Hayter, that if the roller of any existing lock gate were taken away, the gate would work just as well without it.

ernon-
urt. Mr. L. F. VERNON-HARCOURT said, the most essential points in designing a lock gate were the form and the rise. He believed it would be generally admitted that the best form was a continuous circular arc when the gates were closed, and that the best rise was one-third of the span. On account, however, of the natural objections that were raised, namely, that the gate recesses went too far back into the wall, if there was a great curve on the gate, and that with an increased rise there was an increased length of lock, the Author preferred taking the form for a gate of about 60 feet span, shown on Fig. 42, vol. lviii. Mr. Vernon-Harcourt thought that the ordinary rise would be found to be nearer one-fourth of the span than one-sixth. That was the rise given to the dock gates described by Mr. Kingsbury[1] which were erected at the Victoria docks, and a similar rise was given to the gates of the Albert dock at Hull, and to those at the Avonmouth docks, and to the gates at the dock with which he was, himself, more intimately acquainted—the south dock of the West India docks. Fig. 5 showed one of the gates of the south

FIG. 5.



The radius of A B is 60 feet. The radius of E D C is 120 feet.

dock.[2] The gates were made in the form of a gothic arch of wrought iron, and resembling, except as to the rise, the one shown

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xviii., p. 445.
[2] *Ibid.*, vol. xxxiv., plate 19.

Mr. Vernon-Harcourt.

by the Author in Fig. 42. There was only one difference in the form, namely, that the outer skin C D E was curved instead of straight as proposed by the Author. He thought it was preferable to have it curved, because at point B in the Author's figure there would be an excessive strength in the gate, whereas, in the other case, the strength was more proportionate. But there was one slight disadvantage in the gates of the West India dock as shown in Fig. 5; namely, with regard to the question of flotation. If there was the same level of water on each side of the gates, as was the case when the gates were opened, that disadvantage would not exist; but in the case of the water being very high on one side and very low on the other (which would especially apply to the outer lock gates at low water spring tides) the pressure tending to cause flotation must not be reckoned merely over the area between the skins A B C D E, but the total area A B C F E must be considered. Taking into account merely the area between the skins, he had found, in calculating how much water would have to be put into the gates, that about 7 feet depth of water would counterbalance their tendency to float; but taking the whole area—including the piece beyond the skin, which was added in order that the sill might be made straight—it was necessary, allowing for an extreme case, that 11 feet depth of water should be put into the gates. Accordingly, when those gates were worked, they had between 3 and 4 feet more water in them than was required at that time. For this reason he thought it would be better to make the sill curved in gates of that kind. Of course there were disadvantages in curved sills, chiefly in the matter of fitting the woodwork of the gate to the sill, and a straight line, as far as the granite sill was concerned, was rather easier to dress; but these were matters of minor importance. Then, with regard to the question of flotation, when it was seen that it was necessary to put 11 feet depth of water into such a gate in order to prevent it floating, it did seem as if it would be most advantageous to use that flotation and to get rid of the roller. A roller path was awkward to set true, and bedding and setting it on the gate floor stones were costly. It was also necessary to put the gate recess further back than would be required if there was no roller. In the West India docks it was put a foot from the back of the gates, and one of the sluice ways had to be recessed at the top in order to receive the roller and the roller-box. He thought that by adopting the self-adjusting system for counter-balancing flotation, described by Mr. Harrison[1] in the discussion

[1] *Vide* Minutes of Proceedings, Inst. C.E., vol. xxxi., p. 350.

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on Mr. Browne's Paper, on "The Strength of Lock Gates," rollers might be safely dispensed with in gates of not more than 60 feet span. The Author stated that there was a disadvantage in having a recess in lock walls; but he did not see how that argument could apply more to gates of 60 feet span than to gates of 80 feet span. In the Victoria docks, and in the Albert dock at Hull, there were segmental gates, of 80 feet span, not in a straight line with the lock wall when fully opened. It seemed to him rather an advantage for the gate to be out of the way, and not liable to be pressed against by vessels, instead of being in a line with the lock wall. It was important that gates should be formed in the best manner. They were but a small item in the total cost of a lock or a dock; yet they constituted by far the most important part. Engineers ought, therefore, to try so to combine theory and practice as to get a gate as light as consistent with strength, and one that would work as easily as possible.

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Mr. JOHN AIRD suggested that the members should avail themselves of the opportunity of seeing the lock gates which had been completed at the Victoria Dock extension. The gates had been made by Messrs. Brassey and Co., of Birkenhead, and he believed they were as perfect a piece of workmanship as anything of the kind ever seen. Such an inspection would probably enable them to form an excellent opinion as to the merits of rollers and roller paths. He was sure that it would be a pleasure to the Dock Company, and to all connected with the work, to give every information to those who took an interest in the subject, for it was beyond doubt a matter of the greatest importance that the gates should be perfect and be easily worked. The best dock in the world would be a failure if the gates were not in working and in workmanship a success.

owper.

Mr. E. A. COWPER said that in the case of a pair of lock gates, as soon as the shape was settled, it was possible to calculate the strains without difficulty; but if any tolerable sized pieces of floating wood got nipped in shutting the gates, or if rubbish laid on the sill, one gate would not bear fair against the other gate, and the twisting strain brought upon it would be very severe. Every one who built lock gates provided for that, and made them strong enough, but it did away with all the fine theoretical calculations as to the gate acting exactly like an arch or a girder. It might really act as a girder, but there was no support in the middle if the two gates did not touch each other. A gate should be made strong enough, not only to take the pressure when standing against the sill fairly and truly, but to bear straining

or twisting to a considerable extent. That point had not been sufficiently dwelt upon. As to the shape of a lock gate, he agreed with Mr. Hayter. Practically it was endeavoured to make gates of a reasonable shape, with a moderate amount of curvature, so as not to cut away the walls too much, and there was no difficulty in calculating the strength. If the posts and footstep were made strong enough, there was no difficulty in doing without a roller. He knew a case in which the footstep was so flimsy, that it smashed up like a piece of cardboard. When a new one was put in of reasonable strength, it answered perfectly well, and was at work to the present day. Mr. Cowper.

Mr. J. B. Redman remarked, with reference to Fig. 38,[1] for which the Author had made Mr. Bramwell sponsor, as the theoretical form of strongest lock gate, that practically, in the pointing sill, the versed sine of the entire span of a lock was usually made less than one-half of the proportion given by Mr. Bramwell (·33 of the span). In the first volume of the 'Transactions' of the Institution,[2] there was a Paper by Mr. P. W. Barlow on the subject, in which ·25 was the proportion adopted. The usual projection of one-sixth had been practically adopted; but as the span of gates had been so enormously increased to adapt them to the increased size of shipping, it had become a material consideration, because the projection of one-sixth, which was theoretically weak, gave a much heavier gate than theory showed to be necessary, and it had led to the application very largely (especially by private firms, where they were limited by the river on one side, and possibly by a public road on the other, and every inch of length of dock was of importance) of the caisson in lieu of the gate. There were many obvious advantages in the introduction of the caisson instead of a lock gate. In the first place, the caisson might be adapted to the theoretical form laid down by Mr. Phipps. It did away with the necessity of the gate recesses, and the gate platform and the pointing sill were got rid of, as well also as rollers, segment rails, and much complicated and heavy masonry. Of course there was a straight sill for the caisson to abut against, but it materially enhanced the value of a dock, especially a graving dock on a river like the Thames, to have floating caissons of wrought iron where there was a shell approximating to the skin of a ship which was trussed midships, and where there was the advantage of a counter skin to Mr. Redman.

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. lviii. p. 200.
[2] *Ibid.*, p. 217.

edman. take the strain from the outer side, giving the best possible form of gate which might be floated into the river and swung out of the fair way of the channel. That was, of all expedients, the most admirable in such sites. But when the caisson was applied in the manner in which it had been applied by the Government under Colonel Clarke, R.E., Assoc. Inst. C.E., who carried out the great Somerset dock at Malta,[1] with a recess for the caisson to slide into, and an expensive apparatus connected with it, those advantages were almost neutralised by the excessive cost for moving the caisson. He thought those points arose entirely from the fact that the projections given to the pointing sill, being about one-half of what was theoretically necessary, had introduced the large and economical application of caissons to the entrance of docks, especially of private graving docks.

rice. Mr. James Price asked if it was the Author's practice to allow the gates to touch first at the bottom of the mitre-post, leaving them slightly apart at the top—in fact to cut away a portion of the mitre-post, so that, if there was no pressure behind the gate, the mitre-post would be touching at the bottom so as to strike the sill first, then gradually closing at the top as the pressure came against it. He had adopted that method, and had found it greatly added to the staunchness of the gate. It allowed the mitre-post to touch the bottom first, striking against the sill firmly, and then gradually closing by a slight twist of the gate. In that way he had been able to get the gates more staunch, particularly against the sill, than by any other method. He thought that wooden gates possessed an advantage in allowing a certain amount of elasticity, so that they could close at the bottom first, and then by a slight twist close at the top.

landy. Mr. A. F. Blandy said he had some difficulty in replying to the criticisms on his Paper, from the fact that in most cases the speakers either agreed with him, or he agreed with them. Mr. Phipps had referred to the subject of simplicity of calculation. He, too, agreed that simplicity was the great element in all calculations; still, under certain circumstances, it was absolutely necessary to carry the calculation to its conclusion. He had, perhaps, entered a little more elaborately into the subject than he should otherwise have done, in consequence of a memoir written by a French author, in which it was stated that for the most part English engineers did not take sufficient care in their calculations of resistance, but rather trusted to their experience and empirical

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxiii, p. 352.

formulæ, which had no other merit but simplicity. Mr. Phipps had asked why engineers had a prejudice for wood rather than iron gates? He thought they had no such prejudice. It was rather a question of locality and expediency as to which material was best suited for the particular place. Probably in the early days of the profession wood was preferred to iron, because engineers knew more about it, iron being then in its infancy. No doubt wood, if carefully selected, would last, not indeed an unlimited time, but for a considerable period, without deterioration or decay. Some years ago he superintended the alteration of the old Waterloo dock at Liverpool, where it became necessary to take down the existing gates. They were removed to the north end of the Mersey, where they remained on a mud bank "between wind and water" about ten years. Altogether they had been under water every high tide for forty years, subject to the constant change of wind and water during the whole period. The specimen in his hand had been cut from one of the gates broken up in December 1873, after that long exposure, and he thought it was as sound a piece of oak as had ever been seen. When engineers saw a piece of timber like that it was no wonder that in former days they gave the preference to wood, knowing, as they then did, but little of iron. He agreed with Mr. Hayter and some other speakers as to the desirability, as far as possible, of swinging the gates from their anchor blocks; but he should be sorry to make a gate which had not a roller attached, so as to take the strain in case of accident to the anchor block or suspenders. It had been said that a gate was made sufficiently strong, and that the abutments and the heel-post were sufficiently solid, to carry the weight of the gate. That was no doubt true, but he should be loth to trust entirely to anchor blocks. He had seen abutments to heel-posts where, without any apparent reason, the material had given a little one way or the other. Sometimes a crack would occur in an abutment, no one could tell why. Sometimes the mortar itself would give, and sometimes the anchor bolts would be injured by rust, and that would affect the masonry. It was certain that masonry would occasionally move in a very curious way, and he should therefore be sorry not to have a roller to take up the strain when necessary. With regard to the question of the gate being in a line with the side wall, he agreed with Mr. Hayter that the fenders might with advantage be put back 12 inches from the wall. It had not occurred to him to notice this small extent of setting back, as differing from the line of wall. What he had particularly thought of was the fact that the gang-

Mr. Bland

Mr. Blandy. way, at the top of the gate, was more convenient if it formed a straight path with the coping of the side wall. He thought that a shallow gate-recess was in most cases an advantage. In some places there was ample room, and it did not matter what scoop was taken out of the side of the wall; but in others every foot of land was valuable, and there might be a warehouse within 5 feet of the gate-recess, and then it was desirable to keep the gate-recesses as small as possible. He agreed with Mr. Hayter that wood was better than iron near the sea; but there were other cases in which iron was better than wood. Professor Unwin had spoken of the curve of equilibrium. It was, perhaps, a mistake on his part to call the curve by a different name from that by which it was generally known, as it was a good rule to apply the same terms to the same things. He had called it the "line of position of resultants," to identify it with the resultants in the calculations referred to in the course of the Paper. He agreed with Professor Unwin with regard to the line of pressure not passing through the centre of the heel-post. He had omitted to notice this in the Paper; but he was glad that it had drawn forth the opinion of Professor Unwin. No doubt there was a condition of friction round the heel-post which would throw the line of pressure away from the centre as the gate moved under deformation. He had read Mr. Browne's Paper many times with great interest, and had no intention to ignore previous authorities; but if his communication had drawn forth the opinions of others and thrown a little light upon the subject, it might be of some use, and that was all he wished. The object of the Paper was rather to do away with calculations, and his aim had been to reduce the subject to the scope of the chalk line and the set-square. With regard to the twisting strains arising from substances coming between the gate and the sill, there was no doubt that that difficulty would sometimes arise; but he was at a loss to know how to make any definite calculations to meet it. Of course it was necessary to have a margin of strength, and it was impossible to tell at what particular point of the sill the obstruction might occur. Mr. Redman had alluded to the statement of Mr. Bramwell as to the rise being one-third of the span. Theoretically that was the most economical form of gate, taking it simply as a structure, but he did not think that it was necessarily the best form for any particular dock; and Mr. Bramwell, he believed, did not so intend it. The enormous increase of span in dock gates was a question which might now be shelved, for he thought that the increase had reached its limits. He had seen gates of 100 feet span, but he did

pect to see many more. With reference to the question of Mr. Mr. Blandy.
his experience was that gates generally fitted best when
were made to meet first at the bottom; then, as the pressure
ter came on, the heads were drawn together, and the upper
of the mitre-post were brought to form a good joint.

W. H. Barlow, Vice-President, said that not only was the Mr. Barlow.
one of great merit in itself, but it had also elicited a good
ssion. He certainly thought it would be desirable for the
ors of Papers to state what had been done in the same
ion before. Not only had Mr. Browne written upon the
ct, but Mr. Barlow's brother had written upon it forty years
and it was just as well that should be known, and that it
d be seen that the Author himself knew it. Mr. Blandy had
ely admitted the corrections of some of the speakers who
riticised the Paper that there was little left for him to say.
ird had suggested that members should take the opportunity
ing the Victoria docks and the large lock gates made there.
ad seen them himself, and he strongly recommended all who
the time and opportunity to go and see that admirable
nen of workmanship.

onel B. H. Martindale, C.B., R.E., said that the London and Colonel Martindale.
atharine Docks Company would be happy to give every
y to the members who desired to see the gates to which
ird had referred, or any other part of the works now nearly
eted at the Victoria Docks.

Correspondence.

. A. C. Andros observed that the Paper dealt in an exhaustive Mr. Andros.
ble manner with the construction of, and the strains induced
ock Gates, into which he did not propose to enter further
to coincide in a general way with the practical conclusions
ed at by the Author. These conclusions might be carried
er than in the case of curved gates up to 60 feet span.
some modification they would equally apply to gates of the
t size. He failed, however, to see why the rise of the gates
d be fixed at one-sixth of the span. By increasing the
l sine to one-fifth, or one-fourth, the line of resultant pres-
would be brought more in the direction of the length of the
walls, thereby reducing in an appreciable degree the mass of
ry necessary to withstand the thrust of the gates. Then,

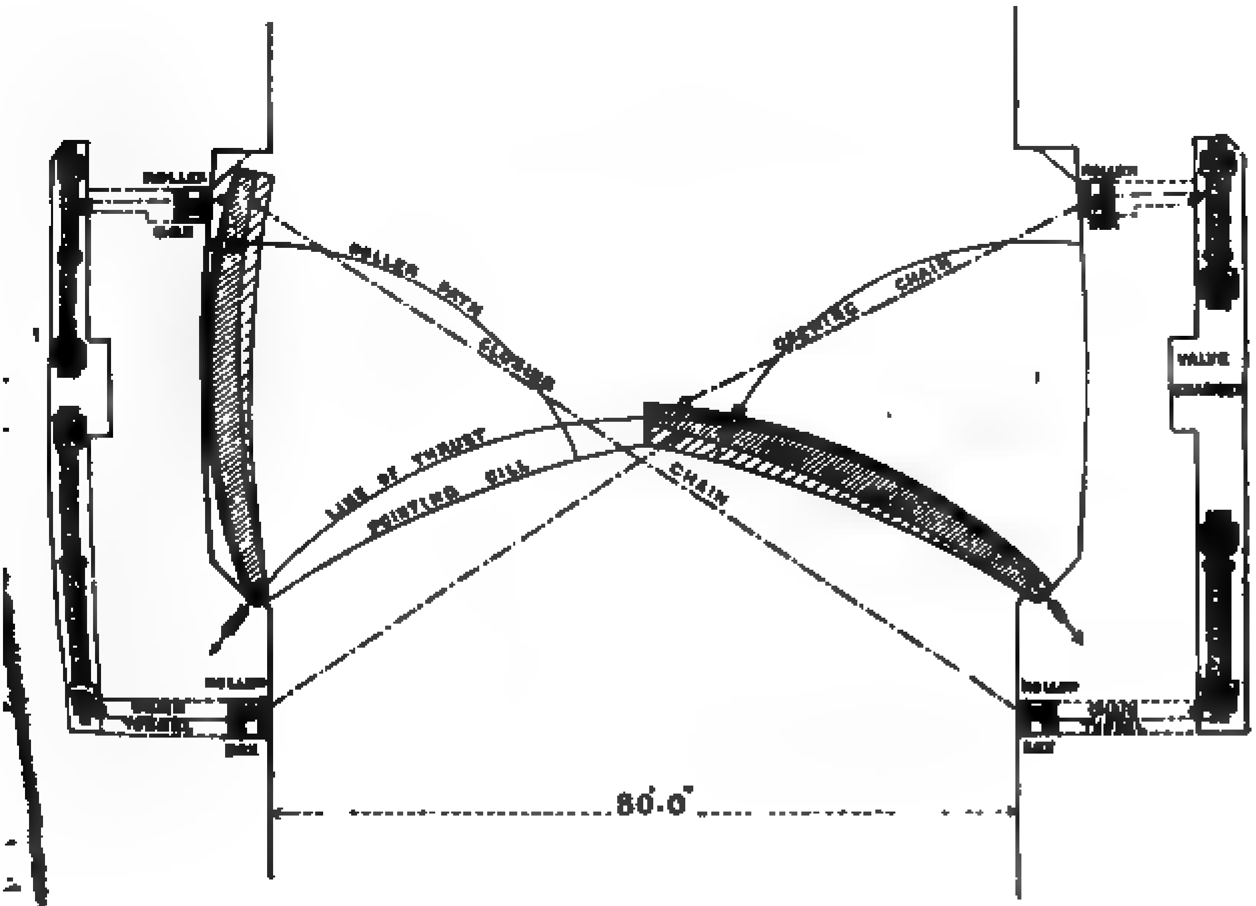
[1] *Vide* Transactions Inst. C.E., vol. i., p. 67.

Mr. Andros. as to the form of the gates; in the case of gates of 80 feet span, and with a rise of one-fifth, or one-fourth, it would practically be almost impossible to make the front of the gate in a straight line from the heel to the mitre-post, the effect of which form of construction would be not only to give unnecessary width to the gate, but also an unduly large area of underside, with a correspondingly heavy upward pressure. As to the Author's advocacy of the straight line in view of its convenience when the gate was back in its recess, this was a mere question of design of footway, which need not conform with the face of the gate, nor need the curved face present any obstacle to its being braced diagonally from the bottom of the mitre-post to the top of the heel-post. This was fully exemplified in the gates now being completed at the Victoria Dock Extension. These gates had been built from the designs of Mr. A. M. Rendel, M. Inst. C.E., and being the largest gates yet constructed in the Port of London, were worthy of a passing notice. They were of wrought iron, plated on the pressure side only. The line of position of resultant force nearly agreed with that advocated by the Author. The span was 80 feet, and the rise 18 feet 6 inches, with a radius of resultant pressure of 56 feet. It would be seen that the face of the gate and of the bottom bar were not in the same plane, and that the latter projected beyond the former. The object of this form of construction was to enable a very large roller to be inserted directly under the centre of gravity of the gate, the result being that absolute perpendicularity was ensured, and that the gate travelled with considerable ease and smoothness—so much so that these gates, weighing 80 tons each, were, during the fitting process, moved easily backwards and forwards by a crab worked by four men.

This brought him to the machinery almost invariably adopted in working large gates by hydraulic pressure, which machinery was, in his opinion, antiquated, barbarous, costly, and unmechanical. It was illustrated in Fig. 6 (page 21), which was a fair type of what had been used for many years. To open and shut one of these gates two hydraulic rams were required, each 16 inches in diameter, one with 12 and the other with 8 feet stroke, 460 feet of 1¼-inch chain, two roller-boxes and chain tunnels, besides numerous pulleys and sheaves. The chains, after going round all sorts of corners and angles in which they were forcibly guided by rollers vertical, horizontal, and diagonal, at the expense of enormous wear and tear, friction, and loss of power, at last reached the hydraulic ram, over which, for convenience sake, they were passed six times, involving an area of ram six times greater than would be necessary

if the ram travelled without this multiplying speed gear. This of course involved largely increased weight and cost in the cylinders and gearing. Moreover the gate, in opening and shutting, was uncontrolled, except in the opposite direction to that it was being tugged by the chain, unless, which was seldom the case, the opposite chain was brought into requisition to check its movements. Another important objection was the large amount of slack which it was necessary to pay out in the closing chains, so as to allow sufficient length, not only to enable vessels to pass between the gates, but also to enable vessels to push the chains over the sill in the event of the draught of water being insufficient Mr. Andros.

Fig. 6.

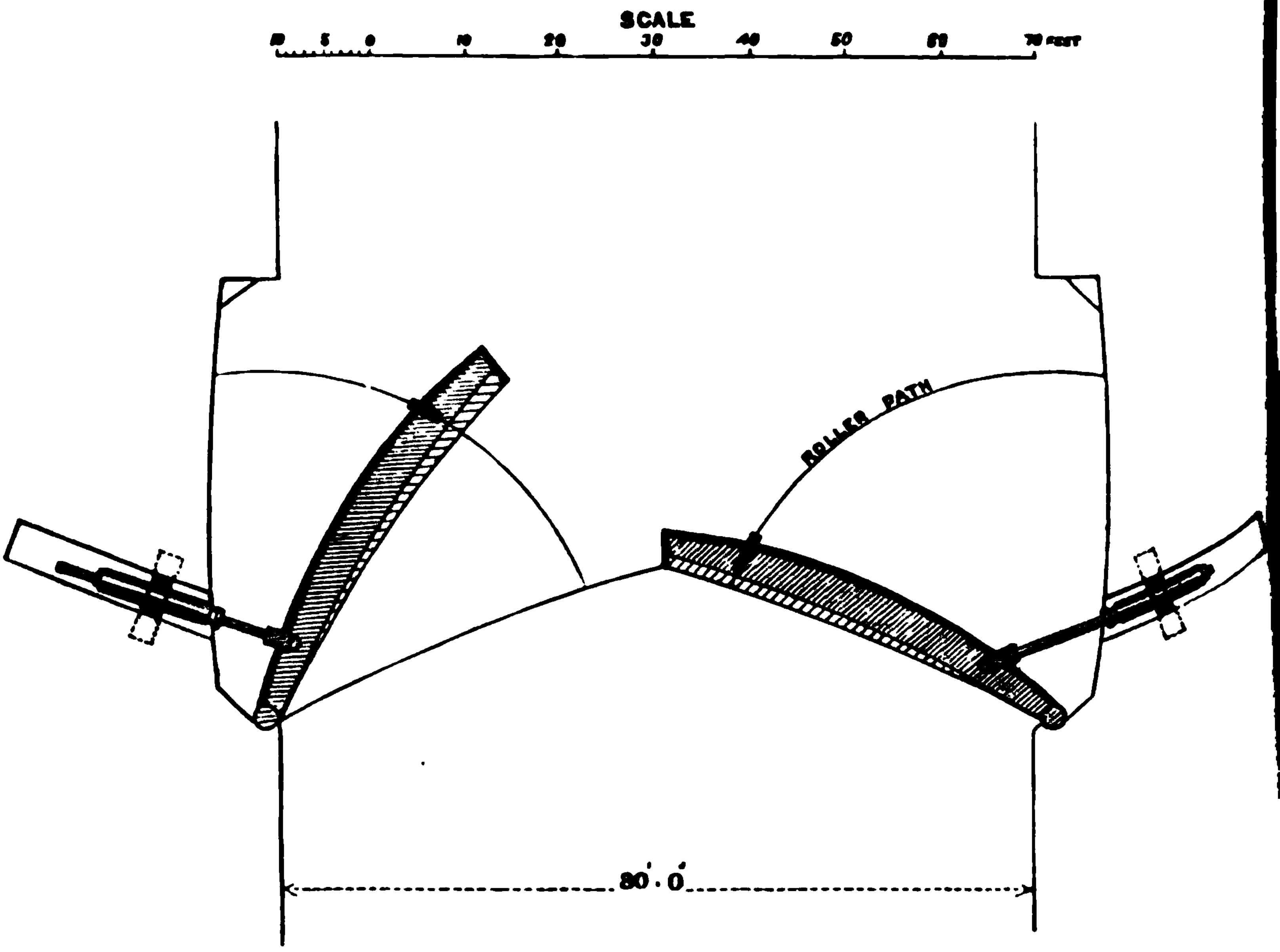


to allow their keels to pass over them—an event not of unfrequent occurrence at the old Victoria dock. In the gates under consideration the amount of closing chain actually required to cause the gate to travel through an arc of 50 feet amounted to no less than 280 feet, to take up the slack of which involved as much power and expenditure of water as would be employed in the actual haulage of the gate.

Numerous designs had been brought out for improvements in opening and shutting gates—such, for example, as machines acting both ways on the gate from the same side of the lock, and also by means of hydraulic engines on the gates them-

Mr. Andros. selves. These, however, still involved the use of chains and elaborate rollers and pullies; and no plan had, he thought, yet been adopted, by which they could be dispensed with, so good as that of a strut such as was used at Antwerp and at Ramsgate, these struts being worked by machinery behind the gate recess. He saw no reason why this strut system should not be improved upon and carried to the fullest extent by direct-acting hydraulic rams and pistons, as shown in Fig. 7—acting, if he might use the simile, like the human arm in opening and shutting an ordinary door. The cylinder would turn on vertical trunnions, and it would be

Fig. 7.



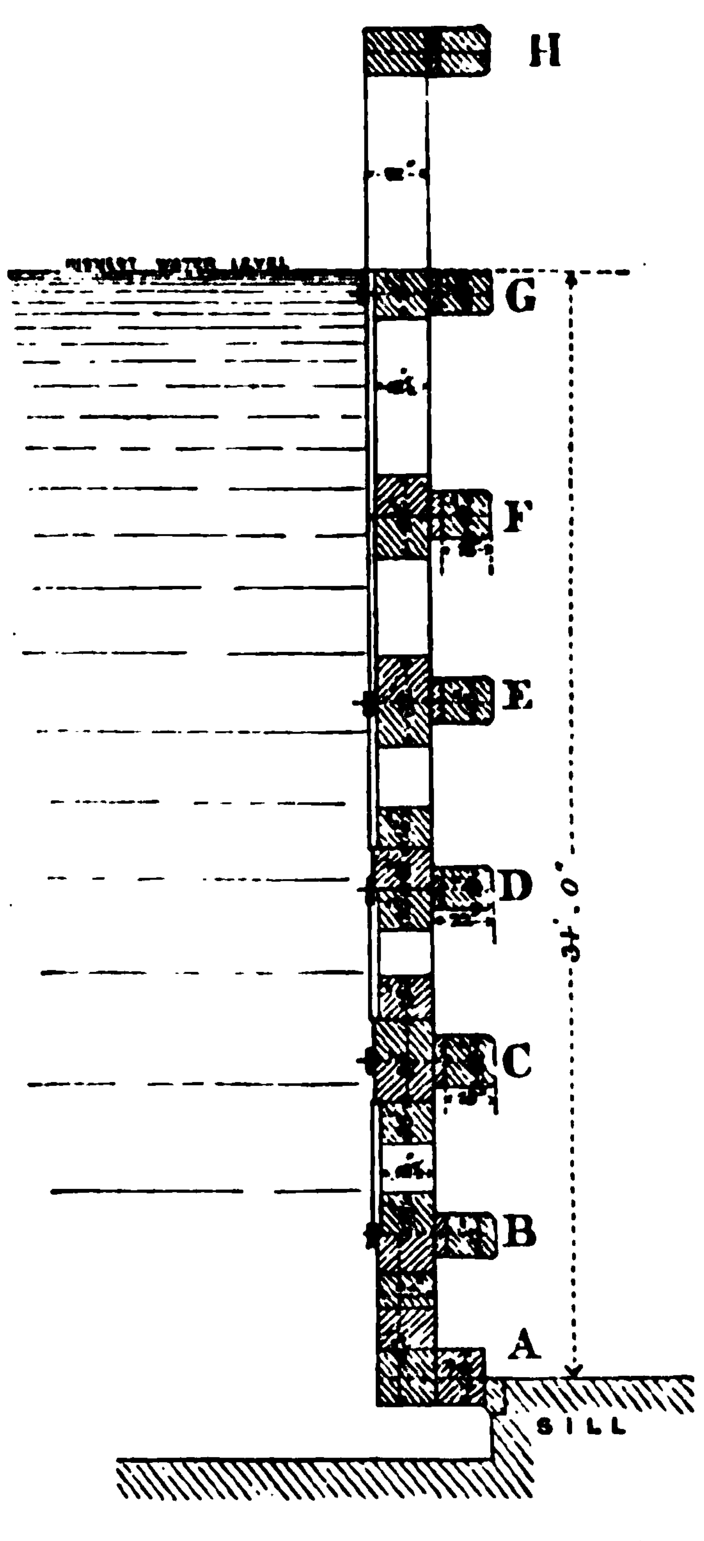
found that the amount of rotation in them would be very small, the difference of angle assumed by the ram from the beginning to the end of the stroke being insignificant. By laying hold of the gate at the top, above the water-level, not far from the heel-post, where the gate was firmly held in position, there would be little or no tendency to pull it over, and the power of the ram could easily be arranged to overcome the leverage against which it would have to exert itself. The gate would be under the absolute control of one man to open and shut it at pleasure; all chains, pullies, roller-boxes, tunnels, multiplying gear, and other apparatus of the kind,

would be dispensed with, and a considerable saving effected in cost of machinery and maintenance. The angle of the ram acting upon the gate would, under no circumstances, be less direct than in the case of the chains now in use, and, in the event of any accident befalling the machinery, the ram could easily be cast loose, and the gate worked by hand tackle, as was now done whenever a chain broke or other interruption occurred in the present complicated system of chains, engines, and rams. The arrangement of these proposed direct-acting hydraulic rams and pistons was a mere question of detail, into which it was unnecessary to enter at the present moment. Mr. Andr

Mr. Barret, Engineer of the Docks and Warehouses at Marseilles, remarked that, as a rule, a lock gate, on the Liverpool system, built in divisions corresponding to the voussoirs of an arch, formed a combination perfectly appropriate, under favourable conditions, to withstand any sort of strains to which it could be submitted. Gates closed against pressure, or while in movement, were always acted upon by considerable forces. In the first case, they had to support, without receiving permanent deformation, the pressure of the water; in the second, they must maintain their rigidity under the action of their own weight, and of the power urging them against a fluid in equilibrium; it being supposed that such power was applied when the water was at the same level on both sides of the gate. The mode of construction advocated in the Paper allowed each separate part of the gate to bear an equal proportionate strain, diminished the strains on the sill by transmitting them to the side walls through the heel-posts, and finally reduced the power necessary for moving the gate by dividing in a convenient manner the reactions on the sockets of the heel-posts and on the rollers. These reactions might at any time, by reason of an alteration of water-level, cause friction greater than that induced by a simple displacement of still water. To put the leaves in movement it would suffice to attach the draught chains sufficiently close to the sill to act as nearly as possible at the centre of gravity of the resisting forces. It was therefore evident that large gates of wood constructed on this principle would be lighter and cheaper than gates of like dimensions on the system adopted, for example, at Havre. Mr. Barret would, nevertheless, remark that, although the arcs forming the body of the gate were distributed over the full height of the leaves, and divided in such a way that each supported, when in action, the same stress and took the same bending moment without prejudice to its elasticity, the way in which they were connected at Mr. Barret

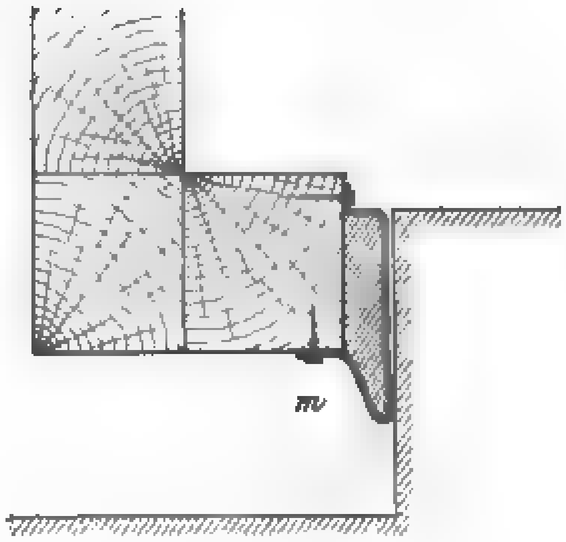
arret. the sill caused them to resist from a different reason. Suppose, for instance, the gate had just been shut, and had no head of water to support, and suppose, as was generally the case, the two braced leaves were in close contact through the whole of their height, the heel-posts bore well against their sockets, and, finally, the lower part of the gate bore truly against the sill. Under these conditions it would easily be seen that directly the load was applied, the lowest member A (Fig. 8) which bore against the sill would not take any deformation, nor be subjected to any bending moment. Section B, which only bore by its extremities against the hollow quoins, would then take, notwithstanding its proximity to section A, by which it was sustained, an appreciable bending moment, and sections C, D, E, F, &c., would take bending moments of continuously increasing amount, in proportion as they were distant from the bottom. From this it resulted that the leaves of the gate, instead of presenting a cylindrical surface, would become warped, and the upper sides of the tie beams would be out of plumb. He thought that this might be remedied by allowing some play between section A and the tie beam proportionate to the span of the gate. The space thus provided should be occupied by a stout filling of some elastic material, which should be attached to the lower part of section A. This buffer, of plaited hemp covered with leather, would take the shape shown in Fig. 9 (page 25). The part *m* would form a tongue, and would absorb any play which might remain between the lower part of the section and the sill. By this means the latter would scarcely have to support any stress, and all the sections subjected to pressure would take the same bending moment. On the other hand, with iron gates, in which solidity and rigidity in every direction were so easily attainable, but which were less durable, owing to their liability to rust inside the cells,

Fig. 8.



the cylindrical form of leaf could be advantageously used for the side opposed to the pressure, a plane surface being used for the other side, or even planes on each side, without much increase in first cost. Such gates should be even more economical than wooden ones, because by calculating all the separate parts, metal might be used so thin that practically it would be inadmissible, on account of its liability to rust, and therefore to wear out more quickly than the remainder of the structure. For the rest, braced gates were so general in England that the engineers of that country had studied and solved all the practical and theoretical questions connected with their construction. Mr. Barret.

Fig. 9.



Mr. F. Guillain, Engineer of the Port of Dunkirk, considered that the Author had ably studied the distribution of the strains produced in one leaf of a lock gate by the combined action of direct water-pressure and the reaction of the other leaf. The use of the "line of position of resultants" exhibited graphically, in the clearest and most elegant manner, the relation between the form of the flange and the efforts of various kinds produced in each section, as also the influence of the fitting of the two mitre-posts. Mr. Guillain

Mr. Guillain would first draw attention to the subdivision of the total water-pressure between the clapping sill and the various horizontal flanges, and which not only resulted from their relative position to the water-level, but, moreover, greatly depended upon the number of horizontal flanges and the relation between their rigidity and that of the vertical pieces. On this matter M. Chevallier's experiments, published in the "Annales des Ponts et Chaussées," 1850, also a statement inserted in the same record in 1867, wherein M. Lavoinne analysed the question mathematically, were well known. The experiments and the calculations yielded concordant results, which in France had frequently served as bases in drawing up plans of large dock gates. Thus, by properly proportioning the rigidity of the vertical pieces to that of the horizontal pieces, a notable portion of the total pressure was thrown upon the clapping sill, and the gate was in consequence considerably relieved. It was evident that M. Lavoinne's formulæ must be adopted with caution; indeed they implied a knowledge

uillain. of the respective coefficients of elasticity in the vertical pieces and the horizontal flanges, and showed that the subdivision of total pressure was perceptibly affected by inconsiderable variations in the relation of these coefficients of elasticity. It was therefore important not to trust to these formulæ before determining, by direct experiment, the deflection suffered under known charges by pieces made of the materials that would be used in construction. By investigating in this way the subdivision of the total vertical pressure, the application of a good system of calculating the horizontal flanges, it became easy to calculate, approximately, the various strains produced by water-pressure on a dock gate. The examination of the Author's graphic constructions, or of the algebraic formulæ commonly used, proved that in flat gates, in which notable bending moments were developed, iron allowed the greatest portion of its resisting power to be utilised much better than wood. In each section of an iron girder the metal could be distributed, care being taken as to the position of the resultant of external forces, so that the greatest part of the iron might bear per unit of surface a strain equal, or nearly equal, to its factor of safety. On the contrary, in a prismatic or nearly prismatic wooden beam, subjected to the combined action of transversal and longitudinal forces, much of the material was wasted, and the fibres of one face alone supplied the whole effort of which the wood was capable. It sufficed that the distance of the line of pressure outside the centre of a section should be more than a sixth of the height of the section to leave useless at least half of the capacity of the longitudinal resistance. It was, therefore, not surprising that gates whose inner surface remained within the concave of the line of pressure could be made lighter, and often more cheaply, of iron than of wood, though the relation of weight in two pieces of greenheart and of iron, of equal length and longitudinal resistance, was about three-quarters, and the present relation of price about three-fifths at least in France. Iron gates, independently of their lesser bulk, possessed also the advantage of affording air chambers, which reduced the weight in the water.

Mr. Guillain had compared wooden and iron gates at Dunkirk, enclosing respectively two locks of the same width of 69 feet, and having the same relation of one-sixth between the rise of the sill and the width. The outer faces of these gates were flat; the wooden ones were 23 feet 6 inches high and 3 feet thick in the middle of each leaf; whereas the iron ones were 27 feet high and 3 feet 7 inches thick in the middle; the lower part of the iron ones, down to mean sea-level, formed a closed chamber, one part of

which afforded flotation, and the other contained water ballast: both pairs of gates could safely bear a load of water corresponding to an equal difference of level of 22 feet between the dock and the sea; in both, the material had been distributed as economically as possible. These conditions afforded a favourable basis for comparison as follows:— Mr. Guillai

—	Wooden Gates.	Iron Gates.
Surface under pressure for one leaf	877 square feet.	984 square feet.
Total weight of one leaf (in air)	50 tons	Iron and wood 49 tons, Water ballast 8 „ } 57
Weight of wood and iron per square foot of surface under pressure	126 lbs.	112 lbs. avoirdupois.
Effective weight of one leaf immersed at mean sea-level.	32 tons	16 tons (including water ballast).
Effective weight of one leaf completely immersed at high water	10 tons	10 tons (including water ballast).
Total cost of one leaf: In 1856, date of construction of wooden gates	£960	
Total cost of one leaf: In 1879, date of contract for iron gates	20 per cent. more than in 1856, or £1,150.	£1,060 Iron not galvanised but scraped, passed through boiling oil, and painted, four coats of paint. £1,300 Iron galvanised and painted, four coats of paint.
Price per square foot of surface under pressure, in 1879	£1 6s.	£1 1s. Iron not galvanised, but passed through boiling oil, and painted, four coats of paint. £1 6s. Iron galvanised and painted, four coats of paint.

The price of equal surfaces was the same for both gates if the iron were galvanised, but the non-galvanised iron gate cost only four-fifths the price of the wooden one. The chances of durability were at least as great for the gate of galvanised iron as for that of wood; they were even almost as great for non-galvanised iron where the paint could be often renewed.

Regarded from the point of easy working, for which the effective weight was an important item, it would be seen that the iron gate would work better as a lock gate, since at the mean sea-level it weighed less by one-half than the wooden gate. Mr. Guillain estimated that in this case iron should be preferred without hesitation. But at high water the two were on an equality as to working, and they would do equally well for a single entrance open only at

[Mr. Gui]llain. slack water of high tide. The only reason for preferring iron was the closer connection between all the parts, and the greater resistance to shocks from ships passing through the entrance.

The foregoing considerations were no longer applicable, and wood held a marked theoretical advantage over iron when the form of the gate was such that the line of pressure coincided approximately with the middle line of the gate. In this case the whole power of the wood to resist compression was brought out, and the wooden gate might, other things being equal, have less mass and be less expensive than iron. The type which seemed best adapted to fulfil these conditions practically was that of the arched gates at Liverpool. Certainly wooden gates of this type might, while needing more caution in use, afford as much facility for working as iron gates; at least in calm weather, and at a single entrance used only at high tide, when the advantage derived by iron gates from their greater rigidity and their air-chambers no longer applied. Yet, while recognising the good service done by wooden gates of the Liverpool type for many years past, Mr. Guillain could not but give the preference to iron gates for almost all practical purposes. Of course he meant such as had flat surfaces outwards, and not curved iron gates, which, with regard to the passage of ships, presented almost all the practical inconveniences of arched wood, and cost more.

As the Author had remarked, the most economical system was not necessarily the most desirable for dock gates; and it might be added that the material which seemed calculated to secure the greatest durability was not necessarily the one to be chosen. When inexpensive and durable gates were inconvenient to use and difficult to manipulate, the only regret was that the gates lasted too long, and that the cheapness of their erection should, unfortunately, have beguiled their makers. The saving of a few hundred pounds in building, and the chance of a few years' prolongation of the life of a gate, were of trifling importance compared with the momentous interests which required that the lock should work as rapidly and as safely as possible for every one of the thousands of ships that passed through it in a year. Safety in working, and rapidity of manipulation in all circumstances, were therefore the principal conditions to be kept in view. Facility for inspection and keeping in good order constituted one of the elements of security. From this point of view four conditions had to be met:

1st. The gates when open must not delay the passage of ships for fear of accidents to either ships or gates.

2nd. The gates must close firmly. Mr. Guillain

3rd. They must open and close quickly, and without requiring much power.

4th. They must be easy of inspection and of maintenance.

1st. For the passage of ships it was convenient that the outer faces should be flat and continuous, and when open should project but little beyond the walls of the lock. A gate concave outwards, forming a bay in the wall when open, or presenting deep recesses, was liable to scratch the paint or sheathing of the ships. Ships might besides, in wide locks and bad weather, strike against the open gate near the heel-post or the mitre-post. These blows did not in general injure flat gates with continuous beams of either wood or iron; nor concave iron gates, all the parts of which were strongly riveted together; but there arose the danger of their dislocating arched concave wooden gates, the system of construction in which did not admit of great resistance to a strain contrary to the usual direction of the water-pressure.

2nd. The resistance of the closed gate presented no difficulty for any system of construction either in wood or in iron, and it might be said that the difference of price between the various systems was generally unimportant. Nevertheless, the mode of construction which threw upon the sill a considerable part of the total pressure, would produce considerable economy of material where the length of the leaf was much greater than its height. It was then necessary to have a few horizontal flanges and vertical members properly proportioned. The extreme case was that in which the gate would comprise only a top flange, vertical girders, a bottom flange-piece upon the sill, and a cleading stiffened by little ribs. In this case the top flange would bear one-third of the maximum total pressure, and the sill would bear the other two-thirds by means of the bottom flange. Mr. Guillain had adopted this system in the iron gates now under construction, and to be put to use in the spring of 1880, at the new Dunkirk dock. Plate 1 showed the arrangements as designed, which were not altered in execution except in a few details. The lock was 69 feet wide; the rise of the sill was one-sixth; the gates were 27 feet high above the sill; the outer surface was flat; so that each leaf had a total length of 38 feet 4 inches, a height of 27 feet 9 inches, and a thickness in the middle of 3 feet 7 inches. The iron cleading covered the whole of the outer surface: it reached about half way up the inner surface, and horizontal iron plates between the vertical girders formed the watertight chamber which occupied the lower half of the gate. The dimensions had been calculated

uillain. so that, under the greatest possible weight of water, such as would be produced by keeping the water in the dock at the level of the top of the gates and completely emptying the lock, no member would have to withstand more than 8,500 lbs. pressure to the square inch, which maximum strain would only be produced in the inner and outer flanges of the top cross-piece, under the most unfavourable conditions, namely, at the line of pressure at the extreme inner edge of the meeting face of the two upper flanges; on the contrary, with the line of pressure at the extreme outer edge of the meeting face, the maximum strain on the top flange would be only 8,300 lbs. in the inner flange (dock side), and 5,000 lbs. per square inch in the outer flange. To accomplish this, the iron had been accumulated as much as possible in the inner flange, the section of which, in the middle of the cross-piece, was equal to nearly fifteen times the section of the outer flange. The weights of the different parts of the leaf were:

	Kilogrammes.	
Top flange	6,800	
Steel shoes and pivot of top flange	800	
Bottom flange	4,500	
Steel socket of bottom flange	400	
Heel-post (tubular)	4,000	
Mitre-post „	3,800	
Five vertical girders	9,200	
Cleading; side and top table of the watertight chamber	9,600	
Little ribs stiffening cleading between the vertical girders	4,200	
Railings, sluices, accessories	3,400	
Total weight of iron and steel	46,700	(46 tons.)
Greenheart linings, oak fence and platform	2,300	
Total weight of leaf	49,000	(48 tons.)

Mr. Guillain had been led to propose this system, not so much to economise a few tons of metal as to secure easy maintenance and manipulation, while allowing the employment of large sluices. Thus each leaf was furnished with two sluices, having together an open surface of 75 square feet. The watertight chamber, reached by means of the heel-post and the mitre-post, was of great height, the men worked standing, and the paint inside could be renewed as easily as in the inside of a ship. Lastly, when in action, the leaf in turning presented only a horizontal strain of 4½ tons at most upon the upper collar and the lower pivot. To effect this,

the second vertical girder from the heel-post formed a watertight joint, the part of the chamber comprised between this joint and the heel-post inclusively contained water ballast, and the other part, on the mitre-post side, being full of air, constituted a float: consequently, when the air chamber was immersed, the centre of gravity of the ballasted leaf was between the heel-post and the centre of buoyancy; it had been possible to proportion the water ballast and the capacity of the air chamber so that the resultant of weights and water-pressures, while retaining a positive value of at least 10 tons, necessary for safety in case of collision from ships, was a little beyond the axis of rotation. As it thus acted upon the fastenings of this axis with a very short leverage, the reaction of the fastenings was very slight. Under these conditions it had not seemed necessary to support the gate upon a roller; it turned freely upon its pivot, occasioning very little friction. Mr. Guill.

3rd. To reduce friction during rotation thus seemed the only means at disposal in the construction of the gate to render its manipulation easy and rapid under all circumstances. Undoubtedly it was possible, with the aid of hydraulic crabs, to overcome the utmost resistance. But the working of a lock should not depend upon the strength of the joint of a tube; it was important to retain when possible the means of easily working the gates by hand power. A lock opening in a tidal port ought not to be stopped even for an hour, because by so doing it might cause the stranding and loss of ships that ought to come into dock. This was why, while supplying the new Dunkirk dock with powerful hydraulic machinery (constructed by Messrs. Sir W. G. Armstrong and Co.), it had appeared necessary to endeavour so to arrange the gates that it might be possible, in case of need, to dispense temporarily with the use of this machinery. With this view, there was a general endeavour in France to avoid resting the gate upon rollers. It had been proved in many cases, especially when the depth of the sill relatively to low water prevented supervision of the rollers and their path, that the roller strongly opposed rotation; it was therefore sought to depend solely upon the upper collar and the lower pivot to support the gate. The gravest inconvenience of this system was that the friction of the lower socket upon the pivot wore it out, and it was a piece that could scarcely ever be renewed. But this inconvenience almost entirely disappeared when, by the means employed in the new gates at Dunkirk, the lateral pressure of the socket upon the pivot, in ordinary work, was reduced to a very slight strain.

Guillain. 4th. If continuity in easy working a lock formed one condition of safety for shipping, another, not less important, was easy inspection and maintenance. It was necessary to contrive means of draining and repainting from time to time the outside of the gates. For this purpose it was best to place a caisson sill at each end of the lock. By giving this sill the form of that of the graving docks in the port, two of the caissons of these graving docks might eventually be used to drain the lock without needing special closing machinery. This arrangement had been carried out in the new Dunkirk lock. In this way, by taking advantage of moments of inactivity in the port, and on condition of having several entrances by the docks, it would be possible to inspect, clean, repair, and repaint the outside of the gates at least once every two years. It was still more necessary to examine and maintain in good condition the inner surfaces of the air chambers, for damp air had a greater power of oxidation than water. If, neglecting to profit by the facilities afforded by iron to construct the gate of a small number of strong and compact pieces, and retaining the system unavoidable in wooden constructions, from the specific weakness of the material, a great many flanges were employed, the interior maintenance was thereby rendered very difficult, not to say almost impossible. In these narrow passages, where sometimes a child could hardly crawl, and most frequently a man could work only crouching, the scraping of rust, cleaning, and painting, could be but very imperfectly done. To keep the metal in good condition for a long time, no rust should be left unremoved; and the best way was to have spaces in the air chambers wide and high enough for men to stand upright in and work at ease. The great specific resistance of iron easily afforded this advantage, as was proved in the new gates at Dunkirk, by enabling the reduction of the number of cross-pieces. It was not always practicable to employ only a single top flange. It had been done at Dunkirk because the arrangement of the masonry was such that there was no fear of fatiguing it by carrying to the top of the wall the 200 tons thrust produced by the single flange; but in all cases flanges could be limited to two or three, and air chambers could thus be got high enough for convenient repairs. An iron gate, maintained in these conditions, seemed to have a chance of lasting as long as the best-treated iron ship. But the chances of durability were increased, and at the same time the maintenance might, without injury, be less continuous if iron were galvanised, though galvanising raised the price of work one quarter, according to present prices in France. It was now very rarely that great iron structures in

French ports were not galvanised. Iron plates, angles, &c., were galvanised one by one after punching; rivets alone could not be galvanised. Mr. Gaillard.

Mr. Druitt Halpin remarked that, as far as he was aware, no reference had been made in the Paper to any of the means adopted for making the joints of the gates watertight. In 1868, the late Mr. Bidder, Past-President Inst. C.E., had built an iron floating dock for the Scinde Railway Company, in which he employed vulcanised indiarubber, fastened directly to the metal by Sterne's process. These joints were illustrated and described in 'The Engineer,'[1] and had, Mr. Halpin believed, given every satisfaction up to the present time. Mr. Halpin.

In 1877 Mr. Halpin employed a joint for dock gates in which the seal was formed by rubber, but the pressure on the gate was taken by timber. This arrangement was illustrated and described in detail in the Proceedings of the Institution of Mechanical Engineers for 1878.[2]

Mr. C. Wawn observed that, while giving the Author credit for the labour and care bestowed on the Paper, he was compelled to regard it, on the whole, as a sample of the tendency to obscure simple mechanical problems under clouds of symbols and formulæ. Mr. Wawn had, at different times, investigated the strains on dock gates, and had estimated and compared the different forms of gate in common use. He believed it to be perfectly correct to take a gate as forming part either of a circular dam, or of a dam generally circular in plan, composed of a number of sides, flat or only slightly curved, the line of pressure being circular, and the compression equal at all points on the line. If the gate also be circular, with the material equally distributed on each side of the line, the whole gate will be equally in compression, and the amount of section required can be computed at once (Fig. 10). As the Author observed, however, it was generally more convenient to make the gate to a flatter curve than that of the line of pressure. If the gate be flattened to the extent of making the line of pressure coincide with the back of the gate (Fig. 11), sufficient metal must be concentrated in the middle of the back to take the whole compression, the other side of the gate being only required for stiffness. If the gate be made still flatter, and the line of pressure pass without the gate (Fig. 12), it becomes a simple matter of leverage to apportion the strains (+ or −) in the two faces. For example, suppose the Mr. Wawn.

[1] *Vide* vol. xxv., p. 98.

[2] *Vide* p. 149.

Wawn.

Fig. 10.

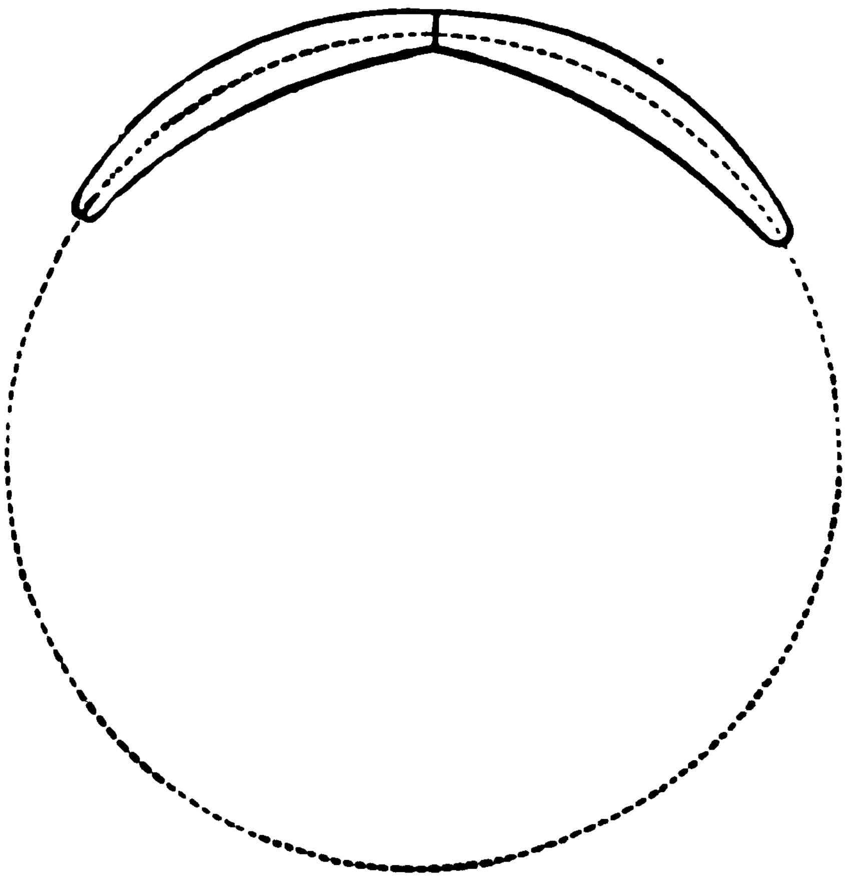


Fig. 11.

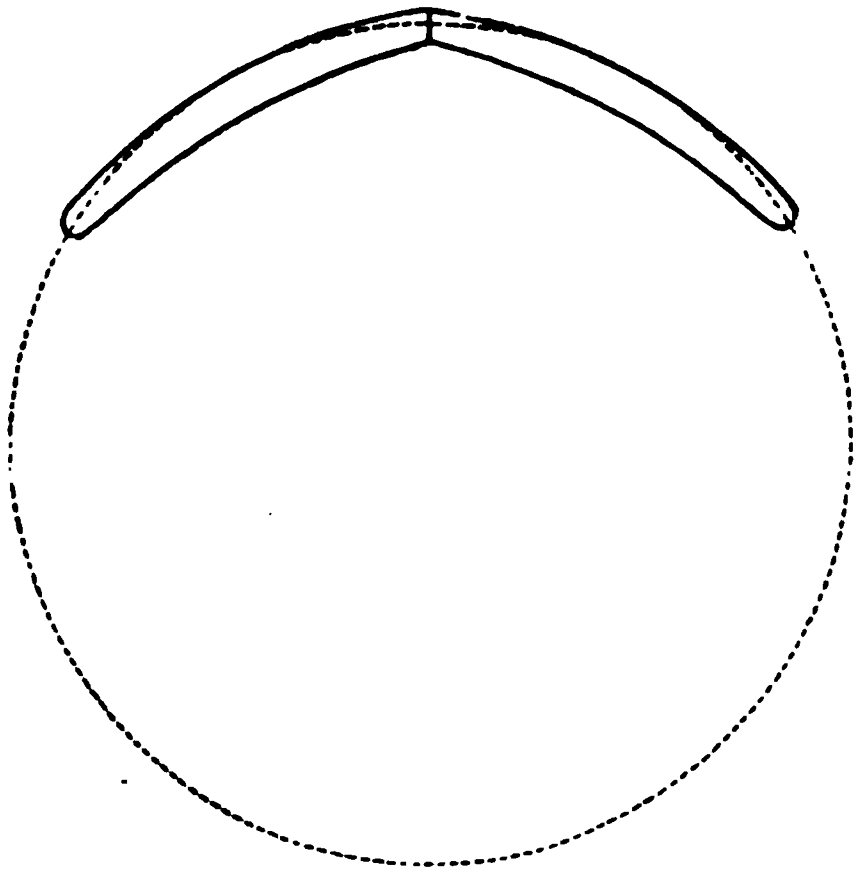
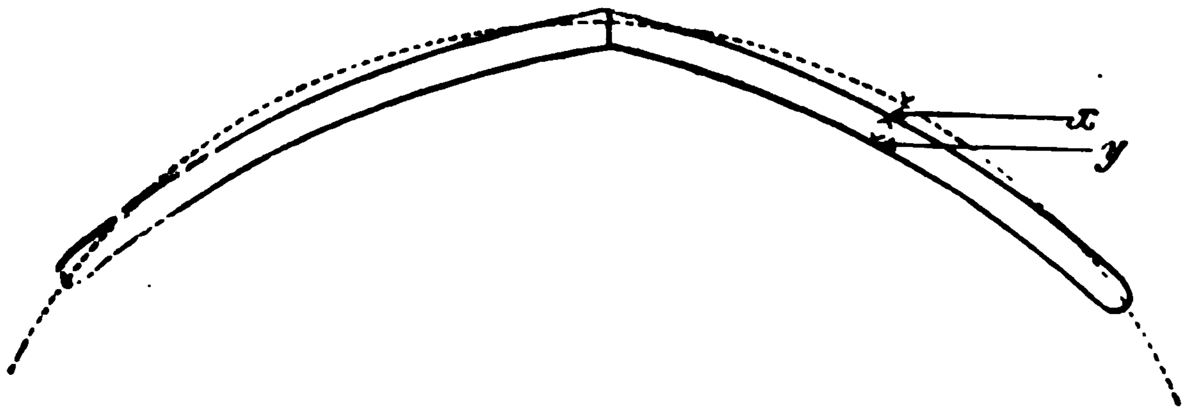


Fig. 12.

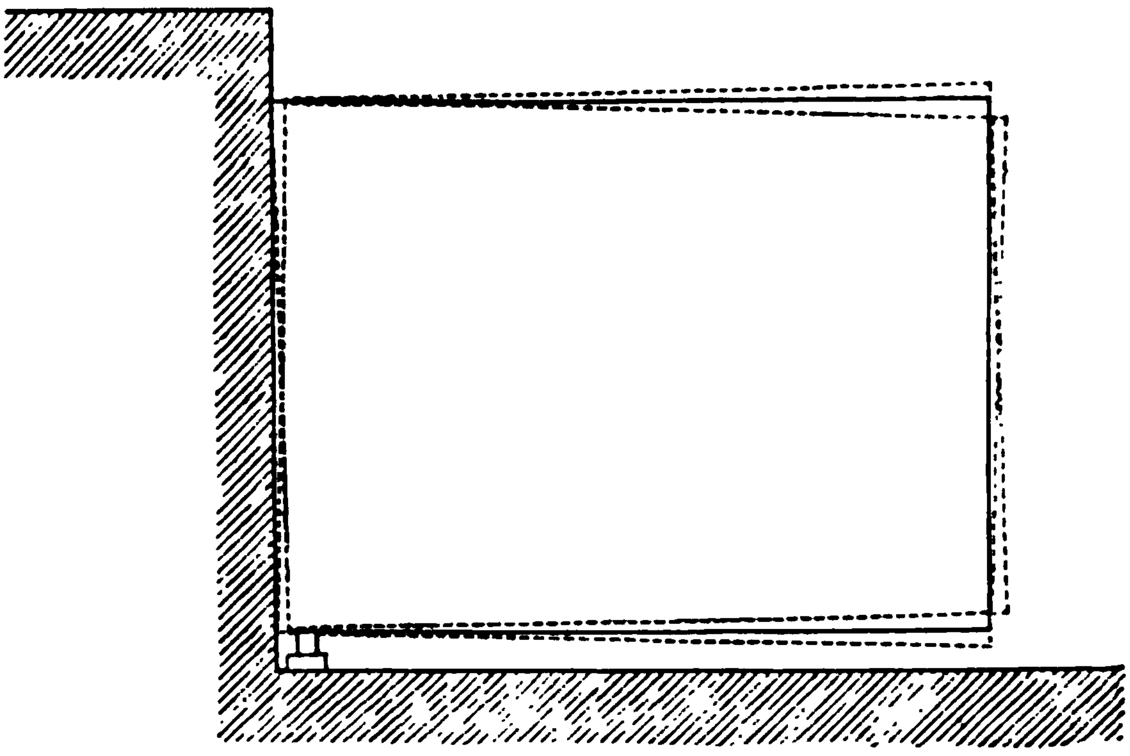


space $x = \frac{y}{2}$, and let z = the compression strain in the line of Mr. Wa
pressure, then the strain in the back of the gate in the middle will be $+ 1\frac{1}{2}z$, and on the front $-\frac{1}{2}z$, the strains in the other parts being obtained in a similar manner. For convenience, wrought-iron gates had been assumed in the foregoing examples; but of course a modification of the same reasoning could be applied to wooden gates. The increase of strain due to any change of form which could possibly take place in a pair of properly proportioned gates by the pressure was so trifling that it might safely be disregarded. In any gate the strains were only those of an arch with the load applied in radial lines, and free from the complications due to unequal loading. In very flat gates he had sometimes found it useful to check the calculations by taking each leaf as a girder carrying its own load, and adding to it the compression due to the angle at which it supported the other leaf as a pillar. With respect to "nipping," the Author assumed an impossible case in taking the strains as passing through the extreme outer or inner edge of the mitre-post. It was clear that the strain could not approach either edge nearer than a distance equal to half the width of timber required to bear the pressure.

Several important points had been raised during the discussion, chiefly with respect to the arrangement of the roller, and to the supposed necessity for springs, or weighted levers, to prevent an undue strain on it while working on an imperfectly constructed or damaged roller path. A good deal of misapprehension appeared to exist as to the action of a gate while in motion. It had been generally assumed that the centre line of the heel-post was at all times absolutely vertical, and the curve described by any part of the gate absolutely horizontal. The bottom of the heel-post was generally loose on the pivot, allowing a clearance of perhaps 1 inch all round. And Mr. Wawn had observed that even with a perfectly level roller path, the heel-post was not always vertical, the bottom sliding horizontally on the pivot, and the timber rubbing on the quoin on one side or the other, according to the direction in which the gate was being moved. This clearance, and a little play in the strap (which it soon acquired by the wear of the heel-post, even if too tightly keyed-up at first), allowed a certain amount of lateral motion to the heel-post; and enabled the gate, although fitting tightly into the quoin when closed and subject to pressure, readily to accommodate itself to any slight inequalities in the roller path, by assuming one of the two positions shown in dotted lines in Fig. 13. Mr. Hayter advocated dispensing with rollers altogether, even in

Wawn. large gates, and no doubt a considerable saving would be effected in the first cost. With buoyant gates working in water subject to little variation of level, rollers would appear to be almost unnecessary, except, perhaps, while fitting the gate in the first instance; but heavy lock gates, working sometimes at or near low water, would certainly be safer and more durable if fitted with properly designed rollers.

Fig. 13.



18 November, 1879.

WILLIAM HENRY BARLOW, F.R.S., Vice-President, in the Chair.

(*Paper No. 1660.*)

"Tunnel Outlets from Storage Reservoirs."

By CHARLES JOHN WOOD, M. Inst. C.E.

THE value of water for almost all purposes was early recognised by man; and the records of Greek and Roman history show what store was set on it, and what large sums of money were annually spent upon securing a plentiful supply. A quantity which was then considered insufficient, or totally inadequate, would now in most parts of England be deemed profuse, for the ancients were not content merely with water for drinking and household purposes, but insisted on having it for their public and private baths, and for ornamental purposes such as fountains.

Owing to the migration of people from rural districts to manufacturing towns in search of work and higher wages, the value of water during the present century has been much more keenly appreciated than formerly; and there are towns and cities where money has been freely spent, and the highest professional authorities of the day consulted, to gain a certain supply.

In order to provide for the wants of a city, town, or district, when the water supply is on the gravitation principle, it is in the first place necessary, after ascertaining the available rainfall, to select sites for, and to construct, Storage Reservoirs; and it is with the usual methods adopted for drawing off the water from these that the Author proposes to deal. The position, design, and construction of the outlet from a large Storage Reservoir are among the most serious matters that come under the attention of an hydraulic engineer, as the safety of the embankment may be endangered, and the risk to many thousands of people in the district increased, from a want of due care on these points.

For the sake of simplicity, the subject has been divided into two

heads—namely, culverts, or iron pipes laid through the embankment, the culverts being of ashlar or brickwork, governed by valves, the position of which may vary in each case; and tunnels round the end of the embankment, in the solid ground, and forming a distinct work. It is mainly on these points that opinion differs, although with reservoirs of a less depth than 25 feet the question occurs of the advisability of using a siphon over the embankment.

The practice first adopted, and which was usual while the construction of storage reservoirs was yet in its infancy, was to lay the supply pipes in a trench in a direct line through the embankment, at the deepest part, to draw off all the water in the reservoir. These pipes were commanded by a valve, or valves, on the outside of the embankment, at or near the foot of the outer slope. By this method the water was allowed to fill the pipe at all times, and leaky joints or defective pipes were supposed not to occur. This practice has proved so dangerous, that it has been abandoned in all embankments of considerable height. No line of pipes so laid, unless in very low embankments, can resist the pressure of the earthwork in settling; and should a leaky joint occur, from want of access to the pipe, nothing short of emptying the reservoir and cutting a drift through the embankment can be undertaken with a chance of success.

This experience led to the adoption of another method, now constantly carried out, although not altogether unobjectionable. This is the building of a culvert of ashlar masonry or brickwork, of some such forms as those shown on Plates 2 and 4, Figs. 2, 4, 17 and 18, in which culvert the pipes are laid. A stopping piece of ashlar is placed across the culvert at the commencement of the line of supply-pipes, usually at or near the foot of the inner slope of the embankment. These precautions were supposed to be effectual against all danger. This, however, does not seem to be entirely the case, as the pressure of the earthwork of the embankment while settling into its final position, and the movement of the puddle in the trench before it is consolidated, caused fractures in even the best ashlar. In fact, it is an open question whether the best ashlar is the most suitable in these cases, as from its rigidity it allows of no movement without sustaining injury. Culverts of first-class ashlar are rendered unsafe (Plate 2, Figs. 2 and 4) by the masonry both inside and outside the embankment being drawn out under extreme pressure, leaving spaces at the joints which have to be plugged. The stones in some instances

have been fractured, and the coping and masonry of both the forebay and the tailbay greatly damaged and displaced, although the workmanship and quality of the masonry may have left little to be desired.

Culverts under an embankment have yet another drawback, in the difficulty of crossing the puddle trench, or, as in many modern instances, the concrete trench. In a puddle trench, especially where the geological formation is not watertight, and where the excavation has therefore to be carried to a great depth before finding a suitable bottom, the puddle continues settling for an uncertain period. The nature of the clay, the method in which it has been put into the trench, whether raw and subjected to cutting and cross-cutting several times, or whether it has been weathered before being sent to the trench, are all factors in the problem. This settlement of the clay is liable to fracture a culvert passing through an embankment, or else to leave a cavity underneath, supposing the culvert to be strong enough to resist the pressure from above. To obviate the danger, a brick or stone pillar has sometimes been built from the solid foundation of the trench to support the culvert. This, however, does not entirely remove the difficulty, as although the portion of the culvert crossing the trench remains rigid, the part immediately on either side is rendered more liable to fracture; and even trenches of concrete are open to this objection. The uncertainty referred to has been in some cases provided against by a slip joint at that part of the culvert passing across the trench. It is of a somewhat larger size than the general section of the culvert, and is independent of the remainder, being capable of a slight vertical movement, so that should the puddle settle, the central portion might also settle without damaging the remainder of the culvert inside and outside the puddle trench. This method would undoubtedly succeed if the pressure above were perfectly vertical; but in high embankments this cannot be the case, as there is for a considerable time a longitudinal as well as a transverse movement, and the possibility of fracture or displacement of the culvert remains almost as before. There are, however, distinct advantages in the system of carrying a culvert under the embankment. In the first place, for speed and economy this method is preferable, although it needs care and the best workmanship to avoid the dangers before spoken of. Usually great care is first taken as to the foundation of the culvert. It is built in a trench, and entirely enveloped in concrete, which when set forms an outer culvert, and the trench in many cases is also of concrete, not puddle, the former material having come into general

use. It is claimed for this class of outlet that first-rate workmanship can be guaranteed, as the whole work is done under broad daylight, and any imperfections—scamping, or the use of inferior materials—can be readily observed and remedied; and indeed many such culverts have been built, and no defects of any sort have been observed. If culverts under high railway embankments were carefully examined some years after completion, many useful lessons might be learned as to the effect of the settlement of the earthwork. The Author is of opinion that lofty reservoir embankments should be undisturbed; and he believes that few, if any, banks made of earth, and left intact, have given cause for alarm. If once a culvert, of whatever description, is allowed to pass through them, there may arise occasion for anxiety, on account of the possibility of a creep of water outside the culvert, even if it should for years appear watertight within.

An alternative method has been adopted, and one designed in consequence of the feeling of the insecurity of culverts carried through an embankment—a feeling which many engineers must have experienced when filling a new reservoir for the first time. This is the driving of a tunnel in solid ground, away from the embankment, but coming round or under one end of it in a V-shape. By this arrangement the embankment is left intact, and indeed might be carried away, but would yet leave the tunnel, pipes, and valve tower safe. In fact the two works are distinct; there is no danger of settlement, and no crossing the puddle or concrete trench. To this plan several objections have been raised, namely that the work being done, as all tunnel work must be done, in comparative darkness, the work might therefore be scamped; that the original position of the strata above the tunnel would possibly be displaced, and thus lead to leakage in certain geological formations far up the valley; and that the backing up of the crown of the arch is a matter of extreme difficulty, and even if carefully watched is apt to be imperfect. These arguments—excepting the one of increased first cost, which may be dismissed if almost absolute security is gained—are not of such a nature as to prove that this plan is open to the serious drawbacks of a culvert under the embankment, since if any leak does occur it is not in the most dangerous place, and does not affect the stability of the embankment. The question of expense certainly is in favour of the culvert; otherwise, taking the stability of the embankment (and it is here the greatest expense occurs) the argument is entirely in favour of the tunnel. Safety is the great test, as most Storage Reservoirs, if the water had to be

run off, or if it unfortunately burst the embankment, would be the cause of an immense amount of damage, especially in large manufacturing towns.

In the earlier examples, the majority of which still exist as originally constructed, the valves were placed at the foot of the outside slope of the embankment. In most cases this is extremely dangerous, as it prevents necessary repairs. Usually, however, a valve-pit is built on the inside of the puddle trench, and is buried in the embankment (Plate 2, Fig. 2). The valves are set at the bottom of the pit, where it is connected with the inside culvert, and are worked from the top by rods and gearing. A stopping of ashlar or brickwork is placed across the end of the culvert on the inside of the embankment, where the line of supply-pipes commences. This plan has disadvantages, as the movement of the earthwork in the bank is liable to cause the valve-pit to deviate from the perpendicular, which creates a tendency to fracture at the point of junction with the culvert, and prevents the rods from working vertically; besides which the water is allowed to go half way through the embankment in the inner culvert, and in several instances has caused great trouble.

Occasionally the line of pipes has been carried through the embankment, a stopping having been placed near the inside toe. The pipes then terminate with a valve having a sloping face, which is worked by draw-rods passing through standards running up the inside slope of the embankment on a line of ashlar stones. The draw-rods are worked by a screw box at the top of the embankment. Three distinct disadvantages occur in this method, leaving out of account the question of the pipes passing direct through the embankment. First, the stones are apt to settle, and the least settlement prevents the rods from working, passing as they do through brass bushes in the standards; secondly, the method of closing the valves places an immense thrust upon the rods; and thirdly, if any mischief of this sort occurs while the reservoir is full of water, access cannot be obtained to the valve, and in any case the least cleanly water of the reservoir is drawn off.

Frequently, however, the line of pipes passing through the embankment is governed by a valve or valves placed in a tower of masonry or iron (Plate 2, Fig. 3) founded on the solid ground, and at the inner end of the tunnel or culvert. Command of the water in the reservoir is thus gained, and all communication as far as the pipes are concerned can be shut off. In the opinion of many engineers this is not sufficient, as it is desirable that free access to the tunnel, culvert, or valve-tower should always be attainable

from end to end, so as to be able to replace any defective pipe or valve by a sound one without either danger or difficulty. For this reason it is desirable to protect the valves inside the tower with duplicate valves outside it, so as to shut off all communication. This may lead to slightly increased expenditure at the outset; but it would be trifling compared with the difficulty in getting at a defective pipe or valve, or with the additional expense, which can never be entirely guarded against even by sinking trial shafts, of encountering faulty geological formations in sinking the puddle trench. This system therefore seems to give an almost absolute command of the water in the reservoir.

It thus appears to the Author, that the greatest safety to a lofty embankment is secured by driving a tunnel in the solid ground distinct from the embankment; and that the best method of governing the supply pipes from the reservoir is by a valve tower at the inner end of the tunnel, which tower should have duplicate valves, one inside, the other outside, so that there should at all times be perfect control over the water in the reservoir.

A few remarks descriptive of some of the reservoirs for the supply of water to the borough of Bradford and for compensation, and the alterations made by the engineer for the works, Mr. A. R. Binnie, M. Inst. C.E., will give an insight into the method adopted on these works during the past four years, and may point out some reasons for discarding culverts through an embankment, in favour of tunnels round the end of it.

The water supply of Bradford is obtained from three distinct districts. It is divided into the High Level, the Intermediate Level, and the Low Level Supplies. The High Level Supply, which is destined for the higher parts of the town, is obtained from the range of hills above the Oxenhope valley, the ridge of which separates it from the drainage area supplying Halifax. The total drainage area available for Bradford from this source is 2,630 acres, for which there is at present only one storage reservoir, the Stubden reservoir, holding about 93,000,000 gallons. Other reservoirs are, however, in contemplation, the necessary Acts having been obtained; and some of these works—including a catchwater conduit about 4 miles long, and a storage reservoir on Thornton Moor having a capacity of 185,000,000 gallons—are being commenced. The geological formation of this district is the Carboniferous; peat, clay, Millstone grits, and shales, with a few beds of coal.

The Intermediate Supply is obtained from a number of natural springs called the Mannywell Springs, situated about 6 miles to the west-north-west of Bradford. The water of these springs, which is remarkably pure and abundant, is stored in two reservoirs, the Upper and Lower Chellow Dean reservoirs, and from these a line of pipes supplies a lower portion of the borough.

The Low Level Supply is derived from the neighbourhood of Skipton, and comprises the Barden, Chelker and Silsden reservoirs. The water from these reservoirs is conducted to a service reservoir at Heaton near Bradford by a conduit. A new reservoir is now in course of construction at Upper Barden, from the designs and under the direction of Mr. Binnie. This district supplies all the lower portions of the borough.

With the last two sources of supply the Author does not propose to deal, as sufficient instances for the consideration of Tunnel Outlets occur in the first mentioned or high-level district.

By the sanction of Parliament, in 1869, the Corporation of Bradford obtained the right of the drainage area of 1,720 acres, part of the 2,630 acres before alluded to, in consideration of making two compensation reservoirs in the Oxenhope valley, viz., the Leeming and the Leeshaw reservoirs, leaving to each of these a drainage area of 510 and 515 acres respectively, and of constructing two intercepting conduits to drain the water from these areas. These reservoirs and conduits are now complete, and the reservoirs given over to the millowners, in lieu of compensation, full of water, the Corporation having been formally relieved from all further action relating to compensation except maintenance. It is with the alterations which it was necessary to make that the Author proposes to deal.

The Stubden reservoir, which was constructed about twenty years ago (Plate 2, Fig. 1), has a top-water area of 11 acres, an available depth of 53 feet, and a capacity of 93,000,000 gallons. It is connected by a line of pipes, 18 inches in diameter and about 5½ miles long, with two large service reservoirs near Bradford, one (Horton Bank) holding 162,000,000 gallons, the other (Brayshaw) 57,000,000 gallons. The Stubden reservoir has for some years been a source of anxiety, as leakage had from time to time been noticed, and a portion of the culvert on the outside of the puddle trench had to be lined with cast-iron plates. It was therefore decided to abandon the culvert through the embankment, and to substitute a tunnel lined with cast-iron plates, in which the delivery pipes were laid. This tunnel (Plates 2, 3, and 5, Figs. 1, 3, 5, 6, 7, 9, 21, and 22) terminates in a cast-

iron valve-tower (Plates 2 and 3, Figs. 3 and 9) connected with the hill side by a light Warren-girder bridge. The leakage in the old culvert, however, did not seem to increase, and it was not until June 1876 that any alteration was noticed. During that month the leakage increased to so large an extent, that it was deemed advisable to run off the water to such a level as should indicate the position of the leak. After lowering the water to below the upper outlet, Plate 2, Fig. 2, the escape of water decreased. But it was finally resolved to remove the old culvert, and to fill in solid that portion of the embankment; the tunnel round the north end of the embankment in place of the old culvert having already been made. The water coming into the reservoir during the reconstruction of the bank was conducted away by the new tunnel outlet, which was then of great service. The work was put in hand at once, and part of the embankment was excavated to the bottom of the culvert. The width of the cutting at the bottom was 14 feet, the side slopes being 1 to 1, and no timbering was required. It was found that not only had the masonry of the valve-pit been pushed considerably out of the perpendicular, but that the line of pipes to the upper source of supply was broken near the valve-pit, and that considerable leakage must have occurred from this fact. The culvert on the inside (Plate 4, Fig. 19) was 2 feet square, built of large, well-worked, and well-laid ashlar, backed with puddle. Behind the puddle, however, a dry rubble backing wall seemed to have neutralised the care taken in selecting the ashlar and puddle. The section of the culvert outside the puddle trench is of the form shown in Plate 4, Fig. 20. The whole of the culvert, excepting a small portion on the outside, which was left for examination, and the valve-pit, and masonry under the valve-pit, were removed and the portion of that embankment re-made in thin layers of about 6 inches, every layer being watered and rammed with wooden rammers. The puddle in the trench was well toothed into the old puddle, which was of excellent quality, and also into the natural ground on which the embankment was formed, and was carried to the top bank level. The outer slope of the embankment was considerably strengthened, by making the width of the top of the bank 20 feet instead of 12 feet, as originally constructed, and adding this amount to the outside slope. The bank has shown no signs of weakness, having settled but a few inches.

The Leeming reservoir (Plates 2 and 4, Figs. 4, 15, and 16), was constructed with a culvert outlet, according to provisions in the Act, to compensate the millowners in the Oxenhope and Worth

valleys. The geological section of the trench shows that a great portion of the seat of the embankment is on clay (Plate 4, Fig. 16). When Mr. Binnie first took charge of the work early in 1875, it was discovered that, although the reservoir had never been filled with water, the settlement of the embankment had so damaged the culvert, having cracked it in all directions, and displaced even the masonry of the inlet and outlet, that it was considered unsafe to fill the reservoir. It was therefore determined by the Corporation, on the advice of Mr. Binnie, and after consultation with Mr. Rawlinson, C.B., M. Inst. C.E., to drive a tunnel similar in every respect to the one in the Stubden reservoir. The tunnel was almost entirely in millstone grit, and has been successfully carried out, although the material was very hard. The old culvert having been abandoned, it was necessary to fill up that portion on the inside of the puddle trench (Plate 2, Fig. 4), so as to prevent the water getting near the puddle. The length of this was 156 feet from the point where it crossed the trench at the slip joint to the inside toe of the embankment. At the junction of the inner portion with the masonry of the slip joint, a wrought-iron shield, 14 feet in diameter (Plates 2 and 4, Figs. 4, 23, and 24), was placed, with the view of preventing a creep of water. A wrought-iron plate was bolted to the centre of this shield, which it had been intended to fit with a special casting for the commencement of the line of supply pipes; but in consequence of the culvert being abandoned in favour of the tunnel, the whole of the interior of the inner portion of the culvert was filled with Portland cement concrete, the masonry of the forebay being taken away and the space filled with puddle.

The Leeshaw reservoir, also situated in the Oxenhope valley, is a compensation reservoir as authorised by the Act of 1869. The geological section of the trench (Plate 4, Fig. 14) will show what difficulties had to be contended against; and as the culvert was only partially built at the time of Mr. Rawlinson's inspection, and the embankment hardly commenced, it was determined not to run any risks, but to abandon the culvert, which was already fractured, in favour of the tunnel clear of the bank. This tunnel, valve-tower, &c., are also complete, and in none of these cases has any leakage occurred, the tunnels and valve-towers being quite dry. In two of these cases the culvert through the embankment had proved unsafe, and it was on this account that the tunnels were adopted.

Having thus made a rapid survey of the works where it was considered advisable to substitute tunnels for culverts, it remains to show their design and construction. As before stated, the driving of these tunnels was principally through millstone grit,

with beds of shale. Each tunnel was 8 feet 6 inches high and 7 feet wide, with a fall of 1 foot in the length. The driving was prosecuted day and night; in many cases the work had to be carefully timbered, and great watchfulness was required to prevent the roof from settling. The inner end of each tunnel, at the point where the valve-tower was subsequently erected, was about 13 or 14 feet below the level of the ground, into which a shaft (Plate 3, Fig. 9) was sunk when the lower part of the tower was built, encased in concrete 1 foot in thickness. At the angle of the tunnel another shaft was sunk (Plate 5, Figs. 21 and 22), which was of great assistance in driving the tunnel, and, being afterwards lined with cast iron, formed a ventilating shaft. The tunnel was made of segments of cast iron, each 2 feet 6 inches in length, weighing 5 cwt. 1 qr. 12 lbs., or 21 cwt. 1 qr. 12 lbs. for the whole ring, and was oval in shape, 6 feet high by 5 feet wide, and 1 inch in thickness of metal. The plates, of which four formed the oval (Plate 2, Fig. 6), had an inside flange 3 inches in width at each end to bolt them together, and a flange 2 inches wide cast outside the centre of each plate to tie into the concrete,[1] which was 1 foot in thickness round the whole length of the tunnel (Plates 2 and 5, Figs. 6, 7, 21, and 22).

Each ring was carefully planed on the longitudinal flanges; and the four segments of every set of plates being bolted together were then planed on the vertical or abutting flanges. This required an elliptical movement, and was in one case carried out by the planing tool revolving while the segment was bolted in a stationary and horizontal position; in the other case the whole segment was made to revolve on the lathe, and a reciprocatory motion was given to the tool in the slide rest. The planing of the plates for the straight portion of the tunnel was a matter of comparative ease, but great care had to be taken in planing the vertical flanges of the curved portion so that they might be truly radial. When this had been accomplished all the curved portion was bolted together in the yard, and the curvature thoroughly tested as set up, before any of the plates composing it were allowed to be sent on to the ground. In this way a perfect fit was ensured.

After a certain length of the concrete forming the cover round the two lower lines of plates had been laid, the two lower plates

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[1] Portland cement concrete, in the proportions of 6 to 1, was employed throughout, and the cement was tested from time to time in one of Mr. V. Michele's machines. The sectional area of the briquette was 2¼ square inches. Each briquette when made was steeped in water for seven days, after which the average pressure sustained was 700 lbs.

were run in on a tramway, and bedded on the concrete ready to receive them, care being taken that the grooves were well grouted with cement. A number of the bottom plates having been thus set, and backed with concrete to their full height, the corresponding tops, bolted together in pairs, were fixed in position by means of an apparatus shown on Plate 3, Fig. 12. When the trolly had arrived at the desired spot, the vertical screw of the apparatus was turned by the wheel at the bottom; this raised the two plates, and at the same time extended two side bars, which enabled them to take their proper positions on the under plates already set. After a little experience the two top plates were sent into the tunnel ready bolted, and the vertical screw of the machine merely lowered them into place. They were then bolted together, and concrete was well rammed around them, care having been taken to clear away all loose material above, so as to make a good and perfectly tight joint with the rock and shale, and also with the concrete round the lower portion. The upper portion required the greatest care and watchfulness in ramming and grouting. This process was carried out in all the tunnels, though it would seem advisable in future to make the oval of the tunnel-lining in two instead of in four castings.

As it was considered advisable to provide further against a creep of water at certain points of the valve-tower where it joined the tunnel, at the bottom of the air shaft (Plate 5, Figs. 21 and 22), and at other places as the nature of the ground seemed to require, recesses were cut into the rock or shale to form stoppings or barriers. These were excavated and filled with Staffordshire blue brick or burnt shale bricks in cement mortar, well grouted.

The tunnel connection with the two lowest rings of the tower was of a considerably larger diameter than the ordinary section of the tunnel (Plate 3, Fig. 9), into which this, the end of the tunnel, projected, the connection being made by a cast-iron gland and gaskin. This was screwed up to the inside of the connection, and a wrought-iron bulkhead, in two segments bolted together, was fastened against it. The upper half of this bulkhead could be removed to allow of the entrance of a workman for repairs. The supply-pipe passes through a gun-metal bush in the bulkhead, and the lower plates of the tunnel were filled with Seyssel asphalt to a level with the top of the bottom flange, or to a depth of about 3 inches, thus giving a level floor on which the cast-iron chairs supporting the pipe rested.

The valve-tower was in each instance of cast iron, as in the case of the tunnels, but was circular in form, and composed of five

segments in the Stubden valve-tower (Plate 3, Fig. 9). When the erection had been carried up to the top, all the horizontal and vertical joints were caulked with iron borings and sal ammoniac. This method answered well; but in the case of the other towers, at the Leeming and Leeshaw reservoirs, it was considered advisable to cast the rings whole, and to make them somewhat like socket-pipes (Plate 2, Fig. 8). This allows of a much better joint; and with the excellent foundries at hand no difficulty was experienced. Although this plan was followed here, the former method would seem preferable for works abroad, or remote from foundries of a first class character; as, from their great weight—the heavier rings being 3 tons 6 cwt., or 16 cwt. 2 qrs. per plate—and the difficulty in getting the upper ones in place, considerable trouble might be caused. A crane with a jib of 50 feet had to be employed in these cases, and such cranes are not easily obtainable in the Colonies. The rings of the tower were bolted together by the inside flanges, 3 inches wide, and caulked as before; by this method all the vertical joints were done away with. The rings varied in thickness from 2 inches at the bottom to 1¼ inch at the top. The base-plate on which the valve-tower stands is 7 feet 10 inches in diameter, and has a projection cast on it, on which the vertical stand-pipe inside the tower rests. This stand-pipe (Plate 3, Fig. 9), is open at the top, extends the whole height of the tower, and is 2 feet in diameter at the bottom, diminishing to 18 inches at the top. At three equidistant points from the bottom of the reservoir, or at 15 feet, 35 feet, and 55 feet from the top-water level, branches are cast on the vertical pipe, governed by sluice-valves, attached to which are branches through the side of the tower, connected on the outside with flap-valves, resting on brackets bolted to the external side of the tower.

The inside sluice-valves are connected with the top of the tower by vertical draw-rods passing through brass bushes, and are worked by wheel gearing at the top. On the special casting connecting the sluice-valves with the flap-valves, vertical pipes 3 inches in diameter are fixed, and carried up to the top of the tower, for the expulsion of air while charging the portion between the flap and sluice-valves. At each flap-valve a small pipe connects the reservoir with the portion of pipe between the flap-valves and the sluice-valves, and is governed by a stop-cock. This equalises the pressure of water on and behind the flap, which can then be easily raised by long links worked by a screw-box at the top of the tower. These cocks should be opened before attempting to raise the flaps.

A vertical ladder extended up the tower, with gratings at inter-als, and the valves were placed radially (Plate 3, Fig. 10), so as ɔ prevent the connections from interfering with one another. 'he vertical stand-pipe is joined at the bottom to the supply-ipe; and on the opposite side of the lowest portion of the stand-ipe a branch was cast, on which a blank flange was bolted. This s capable of admitting a man up the supply-pipe in case of stop-age; and at the outer end, where it leaves the tunnel, an air alve was affixed.

At the top of the valve-towers small houses were built (Plate 3, 'ig. 11), the framework being of cast iron lined with pitch pine, o as to protect the valves and gearing from wet. This description vill show that great care was taken to have every part accessible n case of emergency, even the valve-tower being capable of being illed with water without any passing through the bulkhead.

In concluding these remarks, the Author does not presume to ay that the method of having a tunnel and valve-tower as a listinct work is undoubtedly better than a culvert directly through he embankment; but he thinks, when time and money can be pared, a reliable piece of work can be reckoned on by this means. And as the valve-towers and tunnels of cast iron are a novelty in waterworks, and answer their purpose very well, he hopes that his observations may prove of practical assistance in showing one way of dealing with an acknowledged difficulty which has come under his personal notice.

The Paper is accompanied by several drawings from which Plates 2 to 5 have been engraved.

Discussion.

Rawlinson. Mr. R. Rawlinson, C.B., said reservoir embankments were as old as civilisation. Enormous embankments had been made in other parts of the world; but in Great Britain reservoir embanking was comparatively new, the largest banks being mere toys compared with some that had been erected in different parts of India thousands of years ago. The Author had described the former method (he was sorry to say also an existing method) of constructing earthen embankments, having outlets through the made portion of the bank. The late Thomas Telford, the first President of the Institution, in published drawings had shown a canal embankment about 100 feet in height, with a base line on cross section of about 500 feet, the outlet being a cast-iron pipe with an inlet valve on the water side worked by a winch from the top of the embankment. Telford never designed and executed any work, especially in iron, without giving it great consideration; and no doubt in constructing that work he took the greatest possible care to make it safe, as far as human ingenuity could possibly do so; but Mr. Rawlinson had no hesitation in pronouncing it an utter mistake to construct an embankment with such an outlet. It might be in the recollection of the members, that after the failure of the Dale Dyke bank at Sheffield, the Government entrusted to Mr. Rawlinson the conducting of an inquiry into the cause of that failure. Associated with him was one of the most eminent members of the Institution, the late Mr. Beardmore. The Dale Dyke embankment was on the millstone grit. It was, he believed, 100 feet in height; it had a base line on cross section of 500 feet, and it had a fall from the inside toe to the outside toe of 25 feet. There were two lines of pipes in a trench excavated in the rock, laid upon a layer of 12 inches of puddle, and surrounded by puddle. The valves were in a chamber on the outer toe of that line of pipes. There was a puddle trench some 40 or 50 feet in depth, which had been very troublesome with water. It was 15 or 20 feet in width—he did not recollect which. The engineer who constructed the work had been questioned as to how the pipes were carried across the puddle trench, and he described it as being done by scarfing the rock away on both sides, and laying the pipes upon a thick bed of puddle underneath the made portion of the bank, and through the puddle, which was of a different consistency from that of the bank. In his opinion there were several errors in that mode of construction. In the first place he considered it a serious error to lay 500 feet in length of cast-

iron pipes having socket joints beneath an embankment 100 feet in depth at the centre, with valves on the outer end, leaving no possible control over the 500 feet of pipes. Whatever happened to them they were out of the control of the engineer; they must be subject to every casualty that could occur, and the members knew the catastrophe that actually took place. The embankment had barely been carried to its full height—the reservoir had not been brought into full use—when a storm of rain came on and nearly filled it up to the by-wash. The engineer was upon the work, and the embankment began gradually to subside. He was upon the top of the bank when water was going over it. He ran down to the bottom, when some of his friends snatched him out of the way, and in twenty minutes 80,000 cubic yards of the bank were swept down the valley, the entire reservoir of 200,000,000 or 300,000,000 gallons was emptied, and two hundred and fifty human lives were destroyed. After he had made an examination of the embankment, he was instructed by the Government to examine all the great reservoirs in Yorkshire and Lancashire and report upon them. That caused him to turn his attention very carefully to the question of reservoir embankment construction. He found that many reservoirs had failed, but in none had destruction been carried to such an extent as in the case of the Dale Dyke reservoir. The Holmfirth embankment had been carried away by permitting the bank to subside below the overflow or by-wash, leaving it neglected, until an excessive flood came over it and effected its destruction. After examination he had come to the conclusion, and in that respect he differed from the Author, that there were no conditions requiring that a culvert or pipes should be carried through any portion of the made bank. There were many reasons against it, and he would state a few. In the typical case at Sheffield there was solid rock on both sides of the embankment. Assuming that the engineer had determined to leave the embankment intact, not to touch it with any outlet works at all, but to drive a tunnel through the solid rock to draw off the water from the reservoir, he could have taken 15 or even 25 feet as the level of the tunnel on the inside, for the valley being V shaped and rising at the rate of 20 feet in 500 feet, the bottom portion below 25 feet could be of no practical use. He was sure that no practiced engineer having to make a tunnel 10 feet, 12 feet, or 15 feet in diameter in any class of material, would have any hesitation in saying that he would so construct it, and so use the material as to make it absolutely sound, solid, and watertight from the inside to

Mr. Rawlinson.

Rawlinson. the outside. The conclusions at which he arrived were these. An engineer, whether designing waterworks or other works, should not put any portion of the material liable to decay out of reach: he should not bury such material as cast iron under an embankment having a 500-feet base, so that nothing but the destruction of the bank could ever render it accessible for repairs. Iron had a limited life, and with some kinds of water that life was of very short duration. He had seen cast-iron pipes taken out of water, having been soaked twenty or thirty years, that he could break as easily as he could break a piece of gingerbread. He had also seen wrought-iron plates placed where steam, smoke, and sulphur impinged upon them, which, after twelve or thirteen years' exposure, he could break in like manner. He might be permitted to say, though it was no part of the subject under discussion, that he trembled for the bridge at the Westminster station spanning the Metropolitan railway. With such an enormous weight upon it, and with locomotives running under it frequently, so that sulphur and steam constantly impinged upon the wrought iron, it ought to have a casing to protect it, which could be taken down and renewed whenever it was worn out. He was satisfied that if some means were not taken to strengthen or protect the diagonal beam, it was only a question of time when it would show signs of giving way. He did not say it would give way so as to cause a catastrophe, but the elements of destruction were there, and the structure could be easily protected from them. He did not wish to throw discredit upon the work described in the Paper. He had been called in to examine the culverts referred to. Two masonry culverts had been constructed, directly in the teeth of a recommendation that he had previously made, upon the old principle of constructing them in the deepest part of the bank. He was at a loss to understand how any engineer could make ashlar culverts with what was termed a slip joint, a culvert going through 100 feet depth of embankment, and having a smooth, vertical face at the two ends; the slipping portion of the culvert resting upon the puddle in the trench, so that if an unequal settlement took place one portion would be permitted to subside independently of the other, a line of pipes being then designed to go inside and be secured to a wrought-iron disc and come out through the culvert. He could not understand such a mode of construction. It was arranged to slip, and slip it did. As might have been expected, when a masonry culvert was put upon a compressible foundation, the inside was compressed downwards, and the two ends were tilted up and fractured. Of course the Corporation of Bradford

dared not attempt to use the work in that way, and they had to construct the works described in the Paper. Mr. Rawlins

Mr. ORMSBY asked Mr. Rawlinson what Indian embankments exceeded that at Sheffield in vertical height, as he had been employed some years in India, and never heard of any embankments which equalled that of Sheffield either in dimensions or in importance. Mr. Ormsby.

Mr. RAWLINSON said he had heard of an embankment in Ceylon 40 miles in length; and General Cotton had described to him embankments in India with which any in this country were mere child's play.[1] Mr. Rawlins

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[1] "Ancient Public Works of India," being extracts from the History of Ceylon, by Sir Emerson Tennent, vol. ii., pp. 430–431. "The ruined tank of Horra-Bora, the most interesting object in the district of Bintenne" .... "is a stupendous work, a stream flowing between two hills, about 3 or 4 miles apart, has been intercepted by an artificial dam drawn across the valley at the point where the hills approach; and the water thus confined is thrown back till it forms a lake 8 or 10 miles long by 3 or 4 wide, exclusive of narrow branches running behind spurs of the hills. The embankment is from 50 to 70 feet high, and about 200 feet broad at the base. But one of the most ingenious features of the work is the advantage which has been taken in its construction of two vast masses of rock which have been included in the retaining bund, the intervening spaces being filled up by earth-work and faced with stone. In order to form the sluices, it is obvious that the simplest plan would have been to have placed them in the artificial portions of the bank; but the builders, conscious of the comparatively unsubstantial nature of their own work, and apprehensive of the combined effect of the weight and rush of the water, foresaw that the immense force of its discharge would speedily wear away any artificial conduits they could have constructed for its escape. They had therefore the perseverance to hollow out channels in the solid rock; through which they opened two passages, each 60 feet deep, 4 feet broad at the bottom, and widening to 15 or 20 at the top. The walls on either side still exhibit traces of the wedges by which the stone was riven to effect the openings. These passages were formerly furnished with sluices for regulating the quantity of water allowed to escape, and the hewn stones which retained the flood-gates lie displaced, but unbroken in the channel. The tank is now comparatively neglected, and its retaining wall would evidently have been long since worn away by the force of the escaping water, had not the precaution of its builders effectually provided against its destruction."

"The embankment was overgrown not merely with jungle, but with forest trees, which have contributed to give it solidity.

"The stupendous ruins of their reservoirs are the proudest monuments which remain of the former greatness of their country." ... "Excepting the exaggerated dimensions of Lake Mœris in central Egypt, and the mysterious basin of Al Aram, the bursting of whose embankment devasted the Arabian city of Mareb, no similar constructions formed by any race, whether ancient or modern, exceed in colossal magnitude the stupendous tanks of Ceylon. The reservoir of Kohrud at Ispahan, the artificial lake of Ajmeer, or the tank of Hyder, in Mysore, can no more be compared in extent or grandeur with Kala-Weva or Padivil-colom than the conduit of Hezekiah" .... "can vie with the Ellahara canal."

Jackson. Mr. J. JACKSON (of Bolton) remarked, that in the construction of such works as had been described, he would use as little cast iron as possible, and he would have none in places where he could not at all times get at it. It was true that, in several reservoirs in Bolton, about the year 1850, he had put upright trunks in the inside; that, however, was not to control the water, but merely to skim the water from the top, so that after a flood, clean water could always be obtained sooner. In a large reservoir completed within the last year or two, there was a cast-iron shaft, some 70 feet high, with valves at various heights, as it was obligatory to skim the water for the millowners. The valves were connected by a pipe through the tunnel, but except for that reason he would not put pipes inside the stopping of the tunnel beyond the main draw-off valves. He thought that good brickwork or stonework could be made as tight as cast iron, especially where the tunnels were driven through the hill-sides. He would never attempt to build

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Vol. i., p. 467. "In forming the bunds of their reservoirs and of the stone dams which they drew across the rivers that supplied them with water, the Singhalese were accustomed, with incredible toil, infinitely increased by the imperfection of tools and implements, to work a raised moulding in front of the blocks of stone, so that each course was retained in position, not alone by its own weight, but by the difficulty of forcing it forward by pressure from behind.

"The conduits by which the accumulated waters were distributed, required to be constructed under the bed of the lake, so that the egress should be certain and equal, as long as any water remained in the tank. To effect this, they were cut in many instances through solid granite; and their ruins present singular illustrations of determined perseverance, undeterred by the most discouraging difficulties, and unrelieved by the slightest appliance of ingenuity to diminish the toil of excavation.

"It cannot but exalt our opinion of a people, to find that, under disadvantages so signal, they were capable of forming such a work as the Kala-Wera tank, between Anarajaporra and Dambool, which, Turnour justly says, is the greatest of the ancient works in Ceylon. This enormous reservoir was 40 miles in circumference, with an embankment 12 miles in extent, and the spill-water, ineffectual for the purpose designed, is one of the most stupendous monuments of misapplied human labour."

The following description by Mr. Charles Brumell is quoted from page 14 of the "Report on the failure of the Dale Dyke Reservoir, Sheffield," by Messrs. Rawlinson and Beardmore, 20th May, 1864. "The Cummum tank in the Madras Presidency is one of the oldest and largest tanks or reservoirs in India, and offers perhaps the best illustration of successful native works that can be found. The antiquity of the tank is very great, dating, according to native testimony, among the earliest works in Hindoo history. Its extreme length may be taken at 5 miles, and greatest breadth at 3 miles, enclosing a water surface of 8 miles. The bund or embankment of the tank is not formed according to the European

Mr. Jackson.

a tunnel upon soft yielding ground, but would go down to the solid rock. If he could not get the tunnel on solid ground he would dig it out, and fill the cavity with concrete so as to get a proper foundation. He had been accustomed to make reservoirs for forty years, and he had found no difficulty in dealing with brick or stone.

Mr. Watts.

Mr. W. Watts (of Oldham) said it had been remarked that there was no difficulty in constructing a culvert or tunnel through the solid part of an embankment, or otherwise round the end of it. He thought there was some difficulty, and he fancied that Mr. Bateman was of that opinion, inasmuch as in the reservoirs with which Mr. Watts was acquainted, and of which Mr. Bateman was the designer, he had abandoned the idea of constructing a culvert round by the solid ground, mainly, he believed, on account of the difficulty of making the culvert watertight. However carefully a tunnel might be driven round the end of an embankment, dis-

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practice, by throwing it in a straight line directly across the gorge or valley; but it forms an arc—a form, it need scarcely be observed, by which no accession of strength is in any way obtained. The top of the bund is 102 feet above the level of the base, and its breadth averages about 76 feet. . . . The inside slope is 3 to 1 below the water line, and rather steeper above it; the outside slopes are ½ to 1, and 1 to 1 respectively. The outside slope, from that portion which rises from the footway to the top of the bund, is pitched, or paved with stones about 2 feet 6 inches by 6 inches, rising somewhat like steps. The inside slope is very roughly pitched or paved with stones of larger size than those on the outside slope. There are two culverts passing through the bund, one at the south-west and the other at the north-east end. The outlet towers are each provided with two sets of apparatus for discharging the water, each set consists of two plugs and lifting chains for different levels of discharge. The native manner of carrying out this operation will be at once seen by referring to the sketch of a somewhat similar apparatus which is placed at the waste weir of the tank. On the lower side of the bund, two basins or cisterns receive the water, which passes through the north-east and south-west culverts before mentioned. The dimensions of these cisterns are each 35 feet by 30 feet, whence the main irrigating channels proceed. The water-level . . . . when the reservoir is full stands at 94 feet. It is probable that in the wet season the water begins to overflow the waste weir at a level of from 5 to 6 feet below this point. The waste weir or 'calingulah' is not placed at the bund, but at a distance of about 1½ mile from it, and at the side of the tank. The breadth of the waste weir is 232 feet, and along it are placed stone posts, ninety-two in number, 4 feet high, and 1 foot 8 inches by 10 inches square. These posts are meant to receive boards, so as to give at will an additional depth of 4 feet of water in the tank. If the weir is in use, ... the effective relief for flood-water is about 156 feet lineal, until it may have reached above the stones, when the whole length of 232 feet is available. . . . . The water from the weir is carried off by a trench cut through the hills, passing away by a course wholly independent, and falling into the main valley far below the site of the embankment."

Mr. Watts. turbance of geological strata of the sides and roof could not be avoided; and it was through those disturbed measures that water was liable to escape when the reservoir was filled. When a culvert was constructed through the solid rock, if the work was carefully done, and if a sufficiency of concrete was placed on the bottom, and the ashlar, or the brickwork, was made strong enough, he did not think that there was any danger of fracture or leakage. The culvert must cross the puddle trench on concrete brought up from the bottom of the trench, and in no case rest on puddle. He had had fifteen years' experience in making embankments under Mr. Bateman and the late Major Blackburne, and he felt very strongly on the matter to which he had referred. He was now engaged in making four reservoirs, and all the culverts were taken through the deep part of the embankment; but they were taken deep enough into the solid ground. Two reservoirs which he had just finished for the Oldham Corporation, under Mr. Bateman, were working admirably. They were constructed in the manner he had described, and there was no leakage whatever, and not the slightest fracture.

Mr. Fogerty. Mr. J. FOGERTY said, with reference to the Bradfield reservoir, near Sheffield, that he was in the neighbourhood of Sheffield at the time the reservoir burst, and he remained there some days examining its condition. He should like to ask Mr. Rawlinson, who had no doubt investigated the matter more carefully than any outsider could do, whether there was any subsidence in the two pipes which were laid under the embankment? He believed it was stated in evidence that those pipes had not subsided or been fractured in any way. It was also stated in "The Times" and other publications that, after the ends of the pipes were uncovered, a chain of lights had been projected through them, and they were found to be perfectly in line. No doubt that did not affect the question as to whether the mode of construction by culverts or pipes passing through or under the dam was a proper one; but possibly it was one of those cases in which it was extremely difficult to adopt any other course. He believed that ultimately a tunnel was proposed to be carried round the end of the reservoir, but he had never heard whether it was completed or not. It was generally believed that the failure of this embankment, commonly known as the "Dale Dyke," was not due to anything in connection with the pipes, but had arisen from haste in the construction of the bank, and from imperfection in the puddle-dam. It was proved, he thought, that too limited a time was given; an enormous force of men had been employed, and the

latter part of the work was done at a pace which did not admit of its proper consolidation. The result was that the centre of the embankment sank below the level of the by-wash; and when it appeared evident that this would involve the destruction of the dam, after the great rainstorm mentioned, the engineer attempted to blow up the by-wash, during which operation he nearly lost his life. He did not know who the engineer was, but he thought it was due to his memory that it should be clearly known whether he had laid the pipes in a manner afterwards found to be perfectly sound so that they had nothing to do with the destruction of the dam. Mr. Foger

Mr. Rawlinson was sorry that Mr. Fogerty's question had been asked. The failure of the embankment had caused great excitement. There was a strong wish to relieve the engineer from responsibility, and it was stated that the outlet pipes could not have caused the fracture, because they were undisturbed when they were tested. He had full power to have had the pipes bared if he had thought fit; but he consulted with Mr. Beardmore on the subject, and they agreed that it would be inexpedient to do so; for whatever might have been the condition of the pipes, it would not have satisfied the parties who were wishing to contend that there was no fault in the construction, as it was alleged that the embankment had failed by a land slip. It was subsequently asserted that an examination of the pipes had been made by lighting candles placed in the pipes and sighting them; but he was sure that could not be received as a test whether the pipes had moved or not; no test could be reliable as to the pipes moving or not moving, if there had not been a section produced, taken from a known and fixed bench-mark, which had not been moved, and a second level taken over the same line of pipes from the bench-mark, and the two sections contrasted. Nothing of the kind was done, and (as he was compelled to say at the time) it must have been a marvellous land-slip that carried the embankment to destruction and did not move the pipes which lay through the solid substance of the bank at its base. The bank was the worst he had ever seen, being partly made by railway wagons with 4 and 5 feet tips. The outer slope at the bottom of the bank was confessedly rubble material, having no power of resisting water. The inner portion, up to 30 feet, was certainly tight; as it had been tight for some months, the by-channel of the top having broken and let the water into the bottom; but the upper portion of the bank was made in so careless and so loose a manner that Mr. Stevenson of Edinburgh said, "It is not a reservoir embankment, it is a quarry tip." Mr. Rawlinson's version of the failure was that Mr. Rawli

awlinson. the water had got into the thinner portion of the bank at the top, then reached the puddle, and had crept down it; that the pipes had been pressed down in the puddle trench so as to leave a cavity above, and whether that cavity was $\frac{1}{16}$ inch or 6 inches, made no difference, for if the water under 90 feet head once got in, it had free access to escape outside. The subsidence was in the deep part of the bank, and the crest of the bank sank gradually for 400 feet of its length like a bow-string, being 6 feet above the water when the subsidence commenced, and it went down until the engineer was standing over shoe-top in water, when it suddenly gave way. The testing of the pipes afterwards by lighted candles could not, in his opinion, clear up the matter.

Rofe. Mr. H. ROFE said it was no doubt advisable to have the tunnel in a sound foundation, but he did not consider it absolutely necessary to go outside the embankment for this purpose; nor did he think that, if such a foundation was once fairly obtained inside the bank, there was any practical difficulty in making a good sound job through any embankment. There was some difficulty in making the tunnels tight through hillsides, especially in Lancashire and Yorkshire. The tunnels might be put, as far as was known, in sound ground, as beneath the black shale, but there could never be certainty about them for 20 yards. It was much safer, he thought, for the tunnel to be in an absolutely proved foundation, where the material was known to the right and to the left. With the tunnel across the bank, and with the slip-piece properly constructed, it was very safe indeed. It was not a matter of necessity that a slip-piece should fail. He had constructed a lofty embankment from the designs of Messrs. Hawksley, with a considerable depth of trench, and the slip-piece answered perfectly. The Author had said that there was a horizontal as well as a vertical movement. He could hardly follow that statement. Probably the Author meant that there was always a settlement of the puddle such as would be shown on a longitudinal section along the centre line of the puddle trench by a curve varying with the depth, and having its greatest depression at the deepest part of the puddle trench. If he had to put a tunnel through one of the hillsides, he should prefer good brickwork. It was very difficult to get castings properly in their places. In the case of brickwork, if anything was a little wrong, it could be easily set right; but that was not so with rigidly fixed castings. He did not see why a tunnel through an embankment, if properly designed and with a properly constructed slip-piece, could not be made as safe as a tunnel through the hillside.

Mr. Smith

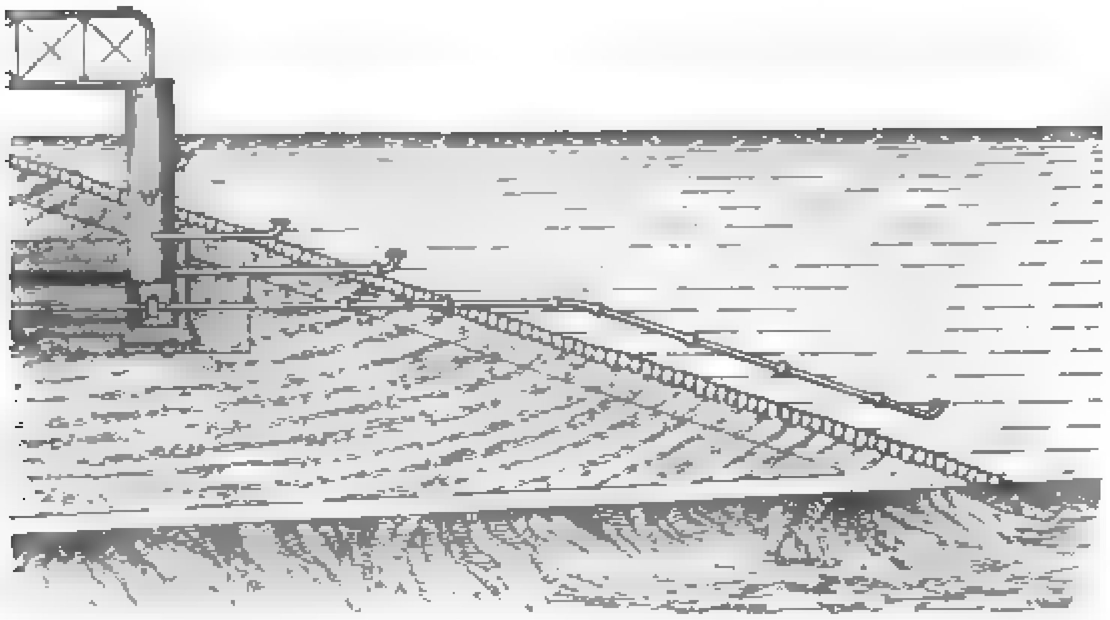
Mr. GRAHAM SMITH contended that a culvert built straight through the puddle bank of an embankment had an element of danger in itself. If iron bolts or timbers were put through puddle dams, water invariably crept along them and caused leaks. The fractures in the culvert mentioned by the Author had all taken place within the vicinity of the puddle bank, and he thought they might have been caused by the water creeping along the culvert and through the puddle bank owing to there being no shoulders of any description in the culvert. If this action took place, the material round the culvert in the vicinity of the puddle would be washed away, and consequently the culvert would fail.

Mr. Latha

Mr. BALDWIN LATHAM thought Mr. Rawlinson had not done justice to what he had effected with regard to the construction of reservoirs. The Author had alluded to a class of reservoir under 25 feet deep, where siphons might be used for conveying the water out. He desired to show that the risk of the tunnels might be diminished, their length shortened, and the cost lessened, by drawing out the water from the lower portion (even in the case of a deep reservoir), by the use of siphons rather than by carrying the whole of the outlet works to the maximum depth of the reservoir. In the case of the Bideford waterworks, he had adopted a recommendation made some years ago by Mr. Rawlinson with respect to that matter. If the water was likely to be drawn down to the lower portion of the reservoir, which always contained the smallest quantity of water, the use of a siphon was quite sufficient to draw the water from it. The water from the other portions of the reservoir was taken from a tower, but the towers were not divided as suggested by Mr. Rawlinson. The inlets were made in the tower at various levels for the purpose of being able always to draw the water from a few inches below the surface, in order to get clear water. With a diaphragm from the top to the bottom, if there was only one inlet, communicating with one side of the diaphragm, the difficulty would be that the water would always be drawn from the bottom of the reservoir, and always be more or less impure. With a diaphragm, therefore, it would be necessary to have a number of inlet pipes into the tower, in order to be able to draw clear water. In the Bideford waterworks the tower was placed in the solid ground near the end of the dam, but the bottom of the tower was about 20 feet above the bottom of the reservoir. The inlet pipes from the reservoir had been arranged in the tower at different levels, but the bottom pipes were carried through and down the slope of the embankment, so as to form a siphon and be able to draw out the lower portion of the water. The siphons

atham. ordinarily formed the discharge pipe, there being a communication with them and the tower which could be closed. Supposing the siphon pipes were not exhausted, there was in the tower a small air-pump to exhaust the siphons of air and bring them into action. He

FIG. 1.



had also used lines of iron pipes, laid directly under the dam, and had never found any failure from them. The iron pipes under the reservoir went under the puddle wall, and were laid on a solid foundation, so that there was nothing to settle below the line of pipes. At Buscot Park he had laid two lines of iron pipes through the embankment. When they were laid, before the embankment was commenced, they were tested under 500-feet head of water. Each line of pipes had collars placed upon it, which were caulked on to the pipes to prevent any water creeping outside them. The collars never came opposite each other, and the lines of pipe were laid about 1 yard apart. When the reservoir was completed the head of water was about 50 feet, and the reservoir would hold 200,000,000 gallons. Very little attention had been paid to the nature of the materials of which reservoir banks were built up. He had lately made a large number of experiments upon the absorption of water by different soils, and some remarkable circumstances had come to light. It should be well known that even clay soils would absorb from 40 to 60 per cent. of water by weight, so that the puddle might contain a larger proportion of water than there was of solid material. Some sandy soils absorbed not more than 20 per cent. of water; but when a sandy soil contained peat, which was a common thing in the moorlands where reservoirs were constructed, it would be found most retentive of water, holding

as much as 80 per cent. of its weight. As all materials immersed Mr. Latha in water lost weight in proportion to the volume of water they displaced, the limit of safety in a sandy soil containing peat (as compared with other soils which only absorbed 25 or 30 per cent. of water) was in the ratio of 20 to 70 or 75; thus it was of the utmost importance that the engineer should pay attention to the question of the nature of the materials of which the dam was to be built up. With regard to the Sheffield reservoir, he was inclined to think that its failure was in a great measure due to hasty and imperfect construction. It had not proper time to settle, and the rapid filling of the reservoir with water caused a correspondingly rapid settlement, and sufficient material had not been put in the dam to allow of this rapid settlement. The consequence was that the reservoir subsided to a dangerous level, and water trickling over the embankment into the loose materials on the outer side of the puddle wall caused further settlement and soon completed the destruction of the dam. The line of pipes carried through this embankment when subsequently examined was reported to be intact, and he could not see how it was possible, by any direct pressure upon the line of pipes, for them to be driven down into the puddle and yet leave an opening at the top as had been stated. The force which drove the pipes down must have been a following force, and, consequently, no opening would remain over the pipes, or it must be assumed that the pipes and the materials under them settled, without the rest of the materials in the puddle wall settling, which was not very likely.

Mr. Bateman, President, believed he had made as many large Mr. Bater storage reservoirs as any man living, about seventy or eighty, independently of smaller ones—covered and service reservoirs—altogether not less than one hundred. But as to the proper mode of discharging water from reservoirs, he was as uncertain as he was forty years ago. Every reservoir, as well as every reservoir embankment, should be constructed after a proper consideration of the particular conditions which applied to it. Out of the seventy or eighty large storage reservoirs which he had made—large in point of area of water surface or in the height of the embankment—there were not twenty in which he had adopted a tunnel as the mode of discharge. At present he was constructing ten or twelve reservoirs, in only one of which was the water drawn off by means of a tunnel. The circumstances were frequently against such a method. Where it could be adopted with security to the embankment itself, or to the strata through which it had to pass, it was an exceedingly good method. Both Mr. Binnie and Mr.

Bateman. Wood had been, he was happy to say, pupils of his own, and he was thankful to find they had given the subject their careful consideration, and had brought a Paper in reference to it before the Institution. But he was bound to say that he thought the system recommended in it was not in all cases applicable, and in any case it was an expensive one. There was no credit due to an engineer who, without reference to expense, executed substantial works; the credit which an engineer ought to aim at was that of executing good, substantial work for, comparatively speaking, a small amount of money. Any amount of substantial work might be executed by an unlimited expenditure. The system brought forward by Mr. Wood, which he did not say was not applicable in certain conditions, and which was perhaps the best mode under certain circumstances, was, nevertheless, an expensive one if usually or universally adopted. It was, in fact, an iron pipe surrounded by concrete in a tunnel which had previously been driven. First of all there was the cost of driving the tunnel, then there was the cost of the iron pipe which was made in segments, and then the cost of the concrete surrounding it. Surely it was better to do away with the iron pipe and the concrete, and to put within the tunnel itself, either brick, which was a very excellent material for the purpose, or stone if the circumstances of the country made stone the cheaper of the two. It was, however, quite impossible to say beforehand what was the best mode of discharging water from a reservoir. Mr. Rawlinson had mentioned some reservoirs with embankments 40 miles in length. He thought he must have meant 40 miles in circumference. The longest embankment of which he had ever read was 12 miles in length, and if the quantity of earthwork contained in such an embankment were compared with the earthwork of the largest embankments in this country, the latter would no doubt, as Mr. Rawlinson had said, be mere toys in comparison with those formerly made. But the difficulties which had to be contended with in making shallow embankments, with such materials as were generally to be found ready to hand, were very much less than the difficulties of constructing high embankments in the rapid and narrow glens of this country. He much preferred a hollow place, where he had not to contend against either the floods of a river, or the cracks and dislocations which invariably accompanied a river, and where, without the necessity of passing water during the construction of the works, he could form an embankment in perfect security upon good solid ground. He had before him the geological sections of embankments, where he had had to go 160 feet deep before getting a

good foundation, through hard rock, which was formerly, and he had no doubt was still, in some cases considered sufficient of itself to tie the puddle wall of the embankment in; but so long as there was a fissure the water would pass along it, and come in contact with the puddle wall as ordinarily constructed. He had long since abandoned puddle; in difficult circumstances he had no confidence in clay. Wherever the water had to come into immediate contact with clay puddle, he invariably enclosed the puddle in concrete, or had a watertight wall, which would intervene between the clay of the puddle and the water of the reservoir. Where, however, there was material which would constitute a quite or nearly watertight embankment, there was no occasion to enclose the puddle within a watertight wall or watertight concrete. But where those conditions were not to be found, where there was not sufficiently good material, and where it was necessary to make an embankment of such loose material as the country itself would afford, it would not do to depend upon the puddle wall only, but it was necessary to go through everything which was of uncertain character, or was permeable to water, and to protect the clay itself against the action of the water by means of a watertight wall. The embankment was represented with a slope 3 to 1 inside and 2 to 1 outside. It might be taken down to any depth, to any stratum which was in itself watertight. It ought to be of watertight material if possible, if the country would afford it, inside particularly, and outside the embankment ought to be made of anything, no matter how loose; the drier and coarser the better to prevent anything like a slip. Many railway embankments had slipped a considerable distance, because the outer part had not been made of dry material. In the case of a fissured rock, there ought to be a watertight or concrete wall between the fissures along which the water would pass in getting to the inside of the reservoir. If the inner portion were made of watertight, or nearly watertight material, all the heart might be clay; but where the strata were broken, it was necessary to protect the clay against the action of the water, or the embankment might fail. It was thirty-five or thirty-six years ago when he first made a tunnel for the discharge of water from an embankment. Since that time he had frequently adopted the same course; but perhaps more frequently he had adopted cast-iron pipes through the embankment itself, or by cutting in a chase in watertight rock, if it could be found; or in hard shale, in which the pipes were placed, surrounded by concrete and made perfectly secure. He quite admitted the importance of securing a perfectly hard and uniform foundation, so Mr. Bateman.

r. Bateman. that the weight of the centre part of the bank might not bend the pipes, as it would do if they were put in the ordinary material, or put through the lowest part of the embankment, without proper precaution. But, it was extremely difficult to determine beforehand the best mode of discharging water from any given reservoir. The circumstances which surrounded the site of the embankment had all to be considered; and that method should be adopted which, under all the circumstances of the case, might appear to be most suitable for discharging the water. Almost all the ancient tanks, as they were called, some of which had embankments 12 miles in length, had failed from one of two causes; either the by-wash, by means of which the surplus water was to be discharged, was not sufficient for the purpose, or the mode of discharging had itself failed, and the water had escaped and cut the embankment down. All the reservoirs in Ceylon were now mere dry pools, or comparatively so. At the present time he was preparing to supply the city of Colombo with water from a large reservoir, to be constructed at a distance of 23 or 24 miles, by gravitation. But he should be sorry that any one should copy the system which he had been obliged to recommend there, in circumstances which were not applicable. He had to make five or six large tunnels through the flat part of the embankment, for the purpose of passing the floods during the period of execution. In May, June, and July 1879, the average rain was more than 20 inches per month, there being more than 60 inches in the three months; and the provision for the purpose of passing the flood waters at that time was such as would not be applicable under circumstances in which the drainage area was not so great; or where the quantity of water to be dealt with was very much less. He had the misfortune nearly forty years ago to give the Institution a Paper upon the construction of reservoirs in Ireland.[1] He then showed the manner in which the water was discharged from the Lough Island Reavy reservoir in County Down. That had unfortunately been copied in circumstances totally different, and he knew of cases in which it had failed. People had supposed that they were copying him, without knowing the conditions which had led him to adopt that particular form of discharge. There was one arrangement that he had introduced (which had been copied by many persons since) in the Manchester waterworks which he constructed thirty years ago, for a self-acting closing valve, in case of a burst, with a reservoir behind

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. i. (1841), p. 168.

it. He saw that the water might be discharged through a burst Mr. Bateman. of the pipe as long as the reservoir continued to supply it with water. It was therefore all important to provide against such a possible dangerous contingency, and he introduced a self-acting closing valve with a vertical diaphragm, so hanging that it was adjusted to a certain velocity; if that velocity increased, the diaphragm moved and set machinery in motion which closed the aperture by a fish-shaped valve, so as to prevent the further escape of water. That had been unfortunately copied in many cases under considerable pressure, and at some distance from the reservoir. It was all very well under 30 or 40 feet pressure and immediately below the reservoir; but at 5 or 6 miles distance, and under 100 feet pressure, it was inapplicable. Although it was made to close as slowly as it could, yet, in the case of a large pipe, concussion behind could not be prevented; the pipe behind was burst, and the mischief which it was intended to obviate was occasioned. He had known that to occur. At the present time he was constructing, as he had said, ten or twelve reservoirs, in only one of which he was adopting a tunnel as a means of discharge. In that case the circumstances were favourable, and in almost all the other cases it would be impossible to adopt a tunnel. In the present Manchester waterworks there were five reservoirs, covering a space 7 miles in length; in four out of the five he had adopted a tunnel as the means of discharge; but he had not gone to the expense which Mr. Wood or Mr. Binnie had recommended. He had sunk a shaft and driven a tunnel through the solid ground, and he had a perfect command of the valves in the shaft itself, so that a man could get at them at all times, whether water was in the reservoir or not, which was an important consideration. He had been contented with discharging the water through pipes which had been firmly fixed in the solid ground, into the tunnel or culvert lined with stone, letting the water flow through the culvert into the main stream below. It would be useless and a waste of money to take the pipes from the valves to the outside of the culvert, and to surround them with concrete; no useful purpose would be served by the adoption of that scheme. Shafts ought, no doubt, to be constructed in such a manner as to make the valves accessible at all times. As Mr. Rawlinson had said, iron pipes had only a limited life; coating them might add twenty years to their life, yet undoubtedly corrosion would take place some time or other, and the pipes would decay; but he did not think that that signified much if the pipes were surrounded by firmly pounded concrete, for by the time the iron

Mr. Bateman. decayed the concrete would be so hard that it would do as well as the iron pipe for the conduct of water. A good deal had been said with regard to the two unfortunate accidents which occurred in the West Riding of Yorkshire—the breaking of the Bradfield dam at the Sheffield waterworks, and the accident at the Holmfirth reservoir. The circumstances of those two reservoirs were totally different. The Holmfirth reservoir, which burst in 1852, was never filled except on the single occasion on which it burst. It was very badly constructed on sandstone rock. It was open at the ends, and open beneath. The water escaped through the fissures of the rock, and gradually washed the embankment down in such a way that the top of the embankment was lower than the top of the swallow which was constructed as a waste weir for the purpose of letting the water off; and not until the occasion on which it burst was the reservoir full. The floods that previously came were not too large to be discharged by the leakage of the reservoir at the ends and below. Everything in the shape of stone was objected to, and the stones from the puddle were piled on each side so as to form rubble drains or walls. For himself, as an old puddle-maker, he had no objection to a little stone mixed with the clay: but the stone should be in a matrix sufficiently surrounded with a large mass of clay, to prevent the water coming in contact with the stone. When the water rose and filled the Holmfirth reservoir, it went over the top of the embankment, then down the rubble drain, and pushed the whole thing out. With regard to the Bradfield bank, he differed entirely from the conclusion at which Mr. Rawlinson had arrived. He did not believe that the pipes had anything to do with the breaking of the bank. It was made upon one side of the valley upon a landslip; on the other side of the valley there was no landslip, the material was hard. After the contract was entered into the direction of the bank was changed; one end of it remained as was originally intended, and the other was turned higher up the valley, and, as the engineer supposed, off the slip, which was then discovered to exist on that side. The section of the embankment was very much the section of all embankments. There was beneath the embankment a flag rock as smooth as a table at an inclination of 1 in 4. After the embankment had burst, and more than two hundred lives were lost, lights were put through the pipes, and whatever might be said against that test, it proved perfectly to his mind that there was no settlement in them. They were laid in a bed of puddle. He did not support that mode, and he had never adopted it; but they were

so laid. The puddle was remarkably well made, a proof of which Mr. Bateman was to be found in the fact that there was no settlement in the pipe itself, so far as it could be detected. The inner part of the bank was of very loose material. If the inside were perfectly tight, the water-pressure would be perpendicular; if it was permeable, the water-pressure would be horizontal. If it was tolerably watertight, the pressure would be at right angles to the slope. As it was, it was horizontal; therefore the puddle trench and the outer part of the embankment had to bear the whole pressure of the water of the reservoir; because the inside slope was permeable by water. The puddle trench was sunk through the flag rock into the shale below; but there on the outside lay the flag rock at an inclination of 1 in 4 as smooth as polished marble. When the pressure came against the puddle, standing as it did on a landslip, and that landslip again upon a smooth flag rock at an inclination of 1 in 4, the whole thing gave way. The engineer was standing at the top of the embankment at the time, and it was a miracle that his life was saved. Mr. Bateman was on the spot immediately afterwards, and the conclusion he had arrived at was that the accident was not due to the mode of discharge, although that mode might have been improved, and was not what he should have adopted or recommended to others with his present experience. He believed the occurrence arose partly from the embankment being placed upon a landslip, and partly because the landslip itself was upon a smooth flag rock. He should not have referred to this reservoir only he should be sorry that the conclusions at which Mr. Rawlinson had honestly arrived should go unchallenged. He was not examined on the subject, and did not wish to be. He did not appear either on the one side or the other; but he had come to a totally different conclusion from that arrived at by Mr. Rawlinson. He would only further say that although he had in a dozen or twenty cases adopted tunnels as a means of discharge, such a method was frequently out of the question. In no case would he put through an embankment a pipe so small that a man could not get at it to examine it or to "telescope" it, as in the case of a fracture or a drawn joint might be necessary. He had known embankments drawn asunder. That was a kind of thing which, it appeared, some members could not understand; but it occasionally happened. Railway embankments sometimes ploughed up the ground for a long distance, some 200 or 300 yards from the foot of the embankment. He would mention one case, that of an embankment 100 feet high, constructed on a layer of 6 or 7 feet of gravel—water-

Mr. Bateman. borne gravel—upon about the same depth, or from that to 10 feet, of clay resting upon rock. It would be thought that that was as good a foundation as could be; but the whole embankment stretched—he could not say how much, but considerably. He knew of one case where the embankment absolutely stretched 30 feet upon clay. Of all materials clay was about the worst, for it was most treacherous and uncertain. Although it was necessary to use it for the core of the embankment, it had to be avoided as far as possible for each toe, where there ought to be the driest material in order to prevent a slip. It could not be too frequently urged that means should be adopted for getting at the valves, or, if one valve got out of order, there should be means of working another. If there were several, it was not likely that they would be all out of order at the same time. It had been common of late years to introduce shafts. Those shafts, if they were in water and light, were objectionable in many ways. The reservoir might be for some time at a certain level; there might be ice 6 or 8 inches thick; and then what became of the cast-iron shaft? As the water rose while the ice bore against the shaft, or fell against it, the cast-iron pipes stood but a poor chance of not changing their form. There should be a substantial masonry shaft, if there was a shaft at all. A cast-iron shaft was too small. It was liable to be acted upon by wind and waves, and by frost to a considerable extent, and it was not a very handsome thing in itself, looking too much like a chimney. A large substantial shaft was tolerably free from the action of wind and water, and from the action of ice, and it was not an ugly thing in itself. Everything should be in the solid ground. There should be no aperture, no culvert, no pipe—nothing through the made embankment, if it could be avoided. The means of discharge should be independent of the reservoir embankment—an entirely distinct and separate work—and access should be obtainable to every part. He was glad the subject had been brought before the notice of the members, because it was one of very great importance. There was great difficulty in constructing waterworks and reservoirs perfectly watertight, and the means of discharge were amongst the greatest difficulties which an engineer had to contend with.

Mr. Binnie. Mr. A. R. Binnie said that in modern times, when reservoirs were made in the neighbourhood of large towns and manufacturing villages, often placed one above the other on the same stream, where any accident would be attended with an appalling loss of life and property, engineers could not be too careful to make everything secure.

Mr. Binnie.

It might perhaps be interesting to the members, and tend to illustrate the subject of the Paper, if he stated briefly some of the reasons which had guided him in selecting the particular form of outlet described by Mr. Wood. In order to prevent misunderstanding, he would first state the meanings which he had attached to the words "Tunnel outlet," and "Culvert outlet." By a tunnel outlet, he meant an outlet driven in the solid rock or shale below the surface by mining, either round the end of the reservoir, as in the case of the Stubden reservoir, or passing deep into the solid rock or shale and below the bottom of the puddle trench as at Leeming and Leeshaw. By a culvert outlet he meant any brick or masonry work which was built under the embankment, or in a cutting which was afterwards filled in and covered by the embankment. Early in 1875, soon after his services were first retained by the Bradford Corporation, he became aware that the old culvert at the Stubden reservoir leaked very badly, and he also found that the valve-shaft was out of the perpendicular. On inquiry, he ascertained that a fortnight after the reservoir had been first filled, eighteen years before, the culvert had become fractured close to the bottom of the valve-shaft, near the place of the puddle wall. The cracks, which he found when he dug down to them, were about 2 inches in width; they had been plugged up with wooden plugs, and the interior of the culvert had been partially lined with cast iron to prevent leakage. That object, however, was not attained, for the leakage went on increasing up to the time when he took charge of the works, and afterwards, until in 1876 the whole culvert had to be dug out. When he first visited the Leeming reservoir it was comparatively a new work. The embankment had never been subject to water pressure; the culvert had been built from end to end of the best ashlar masonry, with a slip joint over the puddle trench; and when he first entered it he found it broken across in two places about 40 feet on the inside of the slip joint, also in two places about the same distance on the outside of the slip portion, and the slip portion itself was jammed tightly between the free ends of the culvert; the arch stones were splintered and cracked, and the masonry displaced, fifty-two of the arch stones were broken, and forty-five of the joints more or less drawn. From the fact that the arch-stones projected from the face of the wall of the valve-wall 1½ inch, it was clear that the whole of the culvert, at least from the lower side of the slip piece to the outer end, had slid bodily down on the bed of clay on which it was founded to the extent of 1½ inch. At the Leeshaw reservoir a culvert of a similar description had been

Mr. Binnie. built, with the exception of the slip joint, and although it was only covered with 10 feet of earth, it had been broken across in one place. After consultation with Mr. Rawlinson, the corporation instructed Mr. Binnie to prepare designs to remove the existing evils, and desired him to commence with the Stubden reservoir, that being the most important, as the source from which the high-level water supply to the town was derived. An outlet, consisting of a cast-iron pipe only, through an embankment of that height was, to his mind, out of the question. Mr. Bateman had stated his experience of the Torside reservoir at Manchester as explained by the late Sir W. Fairbairn.[1] Mr. Hawksley had told what had happened to two lines of pipes which he laid through an embankment at the Liverpool waterworks.[2] Mr. Jackson had described two fractures at the Melbourne waterworks;[3] and the disputed case of the Dale Dyke reservoir had been referred to in the present discussion. It would, therefore, in his opinion, have been absurd to attempt to lay pipes through an embankment of that height. It then became a question whether to adopt a culvert or a tunnel outlet. The objection to a culvert outlet might be viewed in two ways. First, it might be considered simply as a culvert, putting on one side, for the moment, the mode in which the flow of water through it was regulated. A culvert through an embankment, besides all the evils which the Author had noticed, was always, if care were not taken, liable to another—the water in the reservoir might percolate along the outside of the culvert, rupture the puddle trench, and form a leakage which might injure the whole work. Some years ago an interesting Paper was read before the Institution describing the works of the Vartry reservoir for the supply of Dublin.[4] There it appeared that, early in January 1867, a leakage of pure water not larger in diameter than a quill broke out in the outlet culvert. On the 4th of February the leak had increased very much, the water had become discoloured, and a settlement took place, 6 feet in diameter, in the pitching of the outer slope. That was the statement made in the Paper; but it had struck him from what appeared in another part of the Paper that the Author meant the inner slope. Whichever it was, it was clear that the leakage at the base in the culvert was connected in some way with the material above. Mr. Bateman and the late

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[1] *Vide* Institution of Mechanical Engineers, Proceedings, 1866, p. 260.
[2] *Vide* Minutes of Proceedings Inst. C.E., vol. xviii., p. 387.
[3] *Ibid.*, vol. xviii., p. 372.
[4] *Ibid.*, vol. xxxviii., p. 1.

Mr. Duncan, of Liverpool, were consulted on the subject, and Mr. Binnie. when, acting on their advice, the authorities at Dublin cut down into the embankment, they discovered that the water from the inside had passed along between the culvert and the rock, and between the rock and some puddle placed between the masonry and the rock up to the stopping, round the stopping and into the culvert—the first weak point which it found out. To the skill which the President and Mr. Duncan displayed on that occasion the safety of the reservoir was undoubtedly due. Another interesting case of failure of a reservoir through a culvert was recorded in the Proceedings of the American Society of Engineers.[1] The Worcester dam, in the United States, which retained the water for a reservoir of 660,000,000 gallons, was breached and entirely destroyed by a leak which first sprung out in a similar way. He should like to make one quotation from the report of Mr. McAlpine, the engineer who was engaged to reconstruct the works: "Earthen dams rarely fail from any fault in the artificial earthwork, and seldom from any defect in the natural soil—it, the latter, may leak, but not to endanger the dam. In nine-tenths of the cases the dam is breached along the line of the water outlet passages." Mr. Rawlinson had mentioned that there were in India many large reservoirs, much larger than any in this country; but they did not require the same skill in construction, nor involve the same outlay, nor were they attended with the same dangers. They were practically formed by long, low embankments, sometimes many miles in length. The President had referred to some very high embankments, but Mr. Binnie had never seen any in India exceeding 40 feet in height. What had struck him most with the reservoirs in India was, not their magnitude, but the large number of ruined and broken-down works that were met with in travelling through the country. During his six years' residence there, he never neglected the opportunity of examining a broken-down reservoir, because from such works a great amount of knowledge could be gained; and he had found that in every case, with two exceptions, the failures were attributable to defective culvert outlets. The water had either burst the outlet, or it had formed a passage round it, in some cases entirely removing every vestige of the masonry of the outlet. Secondly, as to the mode in which the flow of water through culverts was regulated, it was clear that in a culvert outlet passing through an embankment a stopping of some kind must be introduced at some point. This could be

[1] *Vide* vol. v., p. 244.

Binnie. placed either near the middle of the embankment or at the inner side near the toe of the inner slope. If the stopping were placed, as supposed in the latter case, the flow of the water might be regulated by a valve-tower built at the toe of the inner slope. If that were the case, the culvert from the valve-tower to the puddle trench must be made not only able to support the weight of the embankment but must be made watertight and able to support the pressure of water on the outside of the culvert. If the stopping were placed in the centre of the embankment, the flow of the water through the culvert might be regulated either by valves placed in a valve-shaft—as at the Stubden reservoir—or by valves placed at the ends of pipes at the outer toe of the slope, as was proposed in the case of the Leeming reservoir, and had been actually adopted in the case of the Vartry reservoir at Dublin. There was obviously a vast amount of unequal pressure on the foundation of the culvert at the point where the valve-tower stood. Taking into account that fact, and the varying pressure against the valve-tower, owing to the unequal loading of the earthwork and the differing pressure when the water was in and out of the reservoir, it was not surprising to find cracks occurring. The case at Stubden was not a solitary one. He could mention four reservoirs constructed on that principle where there had been a similar failure. Passing to the consideration of the case of pipes commencing at a stopping at the centre of the culvert, and being governed by valves at the outer end, he would refer again to the valuable Paper on the Dublin waterworks. On the 19th of November, 1866, the valve suddenly closed and cracked the pipe. What happened then? It was impossible to get inside the culvert; it was full of water, and must so remain. Either the reservoir must be emptied, or divers would have to be sent down under 60 feet depth of water with a large wooden ball to put into the pipe. The latter course was adopted, and the ball, after great difficulty, having been placed in the pipe, the valves were repaired; after the repair it was five days before the ball could be removed. Anchors were laid down, divers were employed, purchases were put on, and the pipe was subjected to hydrostatic pressure. During the whole of the time this work was going on, the leakage, which was causing the depression in the embankment, was in rapid progress. It was the consideration of such circumstances, and the fact that the Stubden reservoir was the uppermost of three situated on the same stream in a densely populated manufacturing valley, that had led him to adopt a tunnel outlet. Besides which, a considerable portion of the work could be done without drawing off the water in the reservoir. He had endeavoured to make the work

watertight. He did not attempt to send the tunnel horizontally Mr. Binnie.
out of the sides of the hill, but he started it at right angles from the bottom of a shaft into which the valve-tower was built. Creep of water between the natural strata and the concrete of the culvert was provided for by the brick stoppings. Creeping of water between the concrete and the ironwork was provided for by projecting cast-iron flanges; and, owing to the perfect fit of the interior flanges, the interior of the culvert in dry weather was free from moisture; and the interior of the tower in the same way was dry. Mr. Bateman had spoken of the valve-tower being liable to be injured by wind and the pressure of ice. It was heavy enough to resist all ordinary pressures. Last winter, which was undoubtedly a very severe one, there was ice 18 inches thick in the Stubden reservoir, and the tower, 7 feet 10 inches outside diameter, stood as firm as a rock. There was no pressure of ice upon it; if the water fell a little the ice broke away, and there was nothing to hold on to the side of the tower. Every valve in the tower was provided with a stuffing box and gland between it and the branch on the vertical pipe to which it was attached, and should a valve get out of order a man could be sent to examine it. If he found it defective it could be repaired without altering the level in the reservoir. There were ladders to the bottom, and everything was open to inspection and watertight. By those means he had endeavoured to arrive at such a form of outlet as would not under any circumstances be affected by the subsidence of the embankment vertically, or by the stretching of the foundation horizontally, or by any difficulties in crossing the puddle trench. At the same time he also constructed these outlets in such a way that no leakage would affect the embankment. If in an extreme case a piece of ice did come in collision on a windy night with one of the plates of the valve-tower and crack it, and the tower was filled with water, everything was safe as far as his limited powers could make it, for the watertight bulkhead at the foot of the valve-tower would prevent any further leakage. Three of these outlets had been made, and he was happy to say they had been perfectly successful. One of them had been tested three years, another two years, and the other one year. He did not say that they were the only possible or the most desirable outlets, but he did say that, taking into account the serious risks that would be run in the particular cases that had to be dealt with, they were to be preferred; no culvert could be carried under an embankment without fear of subsidence, fracture, or leakage, and if a burst took place, the effect in the case of

Binnie. Stubden would be terrific. There were two old reservoirs below Stubden reservoir, not made so strongly as modern ones, and he was certain that if the Stubden reservoir were to burst those below would follow. He could not conceive any circumstance which should lead him to advise the corporation to stay their hands in the expenditure of £3,000 or £4,000 when security could be obtained by its expenditure. He acknowledged that that kind of tunnel was expensive, but the advantage was commensurate with it. In many tunnel outlets it would be found that from the stopping in the centre part of the tunnel to the inlet, the inner part was full of water and incapable of inspection under any circumstances. He agreed with Mr. Rawlinson that every part of the outlet should be got at and examined, and, if necessary, removed and repaired. He knew that cast iron was a perishable material. With regard to the backing of concrete, Mr. Bateman had said he believed the concrete would become a pipe in time. The inside was open to inspection at all times, and could be painted as often as desired. The outside of the tower was frequently exposed owing to the exigencies of the works. Every summer the reservoir was emptied, and it could be painted, so that decay was put off to the very latest possible date. In reply to Mr. Bateman's charge of having expensive tastes, he would venture to say that the valve-tower was as cheap as any that could be erected under the circumstances. He had taken the trouble to find out which was the cheaper, masonry or iron, and he would undertake to say that iron was much cheaper, and he would go further and say it was safer. Neither the Author nor he advocate tunnel outlets in all cases, but only where they could be economically constructed, or where they were required to provide against great danger; and as a proof of this Mr. Binnie was now constructing two reservoirs where other modes of outlets had been adopted.

Wood. Mr. C. J. Wood, in reply, said the President, Mr. Rawlinson, and Mr. Binnie had fully convinced him that all the dangers he had pointed out were real and vital ones. He thought that a culvert, in nearly all cases, was not so good as a tunnel. Where the question of expense could be got over, a tunnel was, unless there were strong geological reasons against its adoption, the better plan; he did not care whether it was of brick, stone, or cast-iron, but it should be totally distinct from the embankment. If a hole was once bored in an embankment there was a risk of the water creeping along the culvert. He had pointed out that in the culverts put through embankments there was a tendency to fracture. The President had said that he had made many culverts and some tunnels. Why

were the tunnels made if a culvert would be sufficient? At the Mr. Wood. Manchester, Liverpool, and other important reservoirs, where the embankments were of very great height, tunnels were nearly always adopted. Why was this course adopted if their security was not greater than that of culverts? There was always a risk in crossing a puddle trench or under an embankment, but there was none with a tunnel. As to the comparative advantage of cast-iron and masonry valve-towers, last year there was ice all over the reservoir, but round the valve-tower there was hardly any. There was thin ice all round, but no thick ice formed. Mr. Rofe had said he could not understand what he meant by a horizontal as well as a vertical movement. Mr. Bateman had fully explained this, and Mr. Binnie had referred to the example at Leeming, where the culvert had slid 1½ inch. No doubt culverts were every day safely carried through embankments, but there were other culverts which were not safe. He had not heard of any tunnel which was unsafe. If there was a leak in it it did not matter, but if there was a leak in a culvert it was a matter of vital importance.

Correspondence.

Mr. Charles H. Beloe agreed with the Author, that, in the Mr. Beloe. majority of cases, a tunnel round the end of the embankment of a reservoir, was preferable to either a pipe or a culvert under the embankment. In the case of small reservoirs, however, for the supply of villages, factories, &c., the cost of a tunnel would be too great, and a pipe or culvert should be adopted. Public attention had been drawn to the danger of a pipe under an embankment by the bursting of the Bradfield reservoir, at Sheffield, which had an outlet of this description; but under favourable circumstances, a pipe could be used with safety. He had employed two 9-inch pipes as the outlet for a reservoir for the North Wales Paper Company Limited, having an embankment 44 feet high. The puddle trench fortunately was extremely shallow, and a trench was excavated for the whole length of the pipes to the same level as the bottom of the puddle trench, which was in rock and filled up with cement concrete to the level of the pipes. These were laid with bored and turned joints with deep sockets, which were also filled with lead and caulked. After the pipes had been laid they were tested to a pressure of 65 lbs. per square inch. A diaphragm was placed round each pipe to prevent the creep of water along it, and the pipes were then embedded in cement concrete 3 feet thick stepped to receive the puddle wall. Owing to the nature of the ground he

r. Beloe. was enabled to carry the outlet pipe up the side of the reservoir at an angle of 21°, supporting it on ashlar blocks resting on solid rock. Three valves were fixed to draw the water off at different levels, and the second or emptying pipe had a valve at its termination inside the reservoir. All the valves were of the ordinary sluice pattern, and the spindles were supported by guides bolted to the inclined pipe. The difficulties experienced with the culvert under the embankment of the Vartry reservoir of the Dublin waterworks [1] afforded a good illustration of the objections to this form of outlet. There were several objections to the use of towers of any description, especially in countries where the reservoir was liable to be frozen over, and where large blocks of ice were brought into contact with the tower when the spring floods poured into the reservoir. The Wayoh reservoir of the Bolton waterworks, which had a water area of 95 acres, and a maximum depth of 76 feet, had an outlet formed of a tunnel lined with brickwork 12 feet high and 10 feet wide, and furnished with a brick tower in the reservoir. He thought a preferable mode of construction was that adopted by the late Mr. Duncan, M. Inst. C.E., in the Yarrow reservoir of the Liverpool waterworks, and by himself in the Llannefydd reservoir of the Rhyl waterworks. In both of these reservoirs the shaft was sunk on the centre line of the embankment, but some distance beyond the intersection of the top bank level and the surface of the ground. At Yarrow it had been found necessary to excavate the puddle trench as far as the shaft, which was built of brickwork, surrounding it with puddle. At Llannefydd the shaft was sunk in the rock, and was not lined with brickwork, except a small portion at the top. A brick plug was built in the tunnel on the upstream side of the shaft, in which pipes were inserted and furnished with duplicate valves, worked by gearing from the top of the shaft. The advantages of this plan were the stability of the shaft and the protection of the valves; a subtantial house being erected over the shaft from which the valves were worked. He was now engaged in designing a series of reservoirs for a foreign country, where the winters were very severe, and he was adopting the form of outlet just described. It was intended to erect the dwelling house of the reservoir-keeper over the shaft, to enable him to work the valves without going out of doors; as he was convinced that the valves would be frequently neglected if he had to cross an exposed bridge on to a tower as described in the Paper. In whatever

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxviii., p. 13.

position the shaft and valves were placed, he thought it would be advisable to dispense with pipes in the tunnel; by doing so several valves might be inserted in the plugging or in the tower, as described in the Paper; and all of them could be opened simultaneously, should it be desired to lower the water-level in the reservoir quickly in the case of sudden floods, or of accident to the embankment or by-wash, the whole area of the tunnel being available for the passage of water; a pipe could also be led from the tunnel into a supply tank, to which the main pipe was connected, the surplus water passing away into the old stream course. In this way the supply to the town would always be at the same pressure instead of varying with the level of water in the reservoir. The Paper confirmed the opinion published by him seven years ago, that a tunnel outlet was the best that could be adopted for the majority of large reservoirs. Mr. Beloe.

Mr. A. DUNCANSON furnished the following particulars of the tunnels of the Liverpool Corporation waterworks at Rivington. These tunnels had been in work for twenty-three years; and when examined in the summer of 1879 they were as sound as when first used in 1857. There were in all nine tunnels. Seven of them formed part of the original works, and were built from the designs of Mr. Hawksley. The Upper Roddlesworth tunnel had been constructed in 1863 from the designs of the late Mr. Duncan, and also the Yarrow tunnel, which had been built in 1869. The original seven tunnels, and the tunnel at Upper Roddlesworth, passed through the banks of the reservoirs; but the tunnel of the Yarrow reservoir was cut through a solid hill of shale. This arrangement, he thought, was preferable to the plan of laying the tunnel through the bank, because, in the latter case, where the puddle trench was deep, the ground which was excavated had to be strongly timbered. In filling up with clay this timber had to be withdrawn; the ground gave way more or less, and to some extent injured the ground on which the tunnel rested, and tended to crack the work. The tunnels designed by Mr. Hawksley were of blue Staffordshire bricks, built with wing walls at the entrance and at the outlet, and finished with stone coping. The thickness of the work varied from 18 inches to 27 inches, according to the depth of the bank resting on the tunnel. The Upper Roddlesworth tunnel was built of flat-bedded stone quarried in the neighbourhood. The stones were set radially in rubble work, and were carried up to about half the diameter of the tunnel. On this was built a circular lining of 4½-inch blue Staffordshire brick. The rubble work was carried round the outside of the brickwork to give it strength. The Mr. Duncanson

Duncanson. valve-shaft was in the centre of the bank, just outside the puddle gutter. It stood on a mass of concrete carried up from the bottom of the puddle trench. The bottom of the shaft was formed of flag stones soundly bedded on the concrete; the flags being sufficiently large to have the walls of the shaft built on their ends. The puddle gutter was continued on the water side of the shaft and its foundation. The shaft was lined with parpoints backed with rubble masonry; and the inlet and outlet ends of the tunnel were faced with rockwork. The Yarrow tunnel, driven through the solid shale, was lined with parpoint work, and was finished at the inlet and outlet ends in rock-faced masonry. In constructing the tunnels and shafts, provision was made, and toothings were left out, to give support to the stoppings in building in the valves. In this part of the work great care was taken to have all the bricks cut to fit their particular places, and to soundly bed them in cement. In each of the shafts there were four valves, and two lines of pipes—two valves being on each pipe for facility in case of repair. In all cases the size of the outlet tunnel was determined by the area draining into the stream, and the maximum rainfall; and the tunnel was of such a size as to take the water in floods, during the construction of the works.

Hassard. Mr. R. Hassard stated that where the ground was dislocated, or where it was found necessary to sink the puddle trench to a great depth for the whole width of the valley, it would no doubt be preferable to draw off water from a reservoir by a tunnel, removed as far as possible from the embankment; but where the ground was good, he would certainly give the preference to an outlet culvert, which could be constructed by cutting a deep trench in the hill-side, the culvert being placed on solid ground entirely beneath the bottom of the puddle trench, the space above it being filled in with Portland cement concrete, and the puddle trench for some distance longitudinally on both sides of the culvert protected by cross walls. In this way the embankment would be left practically as intact as by a tunnel, and the whole work could be seen and inspected in progress. He knew by experience the difficulty in tunnelling, in ground which required timbering, of getting the excavated space between the extrados of the arch and the roof made up solid, and he believed it would be scarcely possible in practice to get the upper part of the annular space round the cast-iron plates in the tunnels, under Mr. Binnie's supervision, made up perfectly solid with concrete. He would also much prefer brickwork in cement to cast-iron plates as the lining for an outlet tunnel. It must, however, be borne in mind that immunity from leakage

Mr. Hassard.

depended, not only on the material through which the outlet was constructed, but also in the design and arrangement of the work itself—the failure of the embankment of the Roundwood reservoir of Dublin being a case in point. Here nothing could be sounder than the ground through which the outlet was constructed, and the materials and workmanship were of excellent quality. Yet as soon as the reservoir was nearly filled an alarming leak appeared in the culvert, rendering it necessary to empty the reservoir and cut down the embankment; it was then found that the water had penetrated between the puddle and the brickwork of the culvert in which the stopping was built. Under Mr. Bateman's directions, he having been called in by the Corporation, remedial works, consisting of cross walls of brickwork in cement, and the substitution of concrete for puddle where in contact with masonry, were undertaken. If this mode of construction had been adopted in the first instance great delay in supplying the city with water, and an expenditure of about £15,000 in making good the defective work, would have been avoided.

Mr. Jervis.

Mr. A. Jervis observed that in deciding whether the outlet from a storage reservoir should be by way of a tunnel distinct from the embankment, or by a culvert built in a trench under it, no precise rules could apply, as it rarely happened that any two sites for an embankment were alike, and each case had to be considered on its own merits and natural advantages. In present practice, tunnelling had the preference, but it was questionable if this might not be carried too far. The position for an embankment might be selected suitable for a tunnel, but the stratification of the rock through which it was to be driven ought to have an important bearing in the matter, and on this point the Paper was somewhat deficient. If the rock was of a solid and compact nature, an outlet by tunnelling might be the best, but should the rock be shattered and intersected by fissures or faults, a culvert built in an open trench along the side of the valley under the embankment might be the most judicious way of dealing with it. A tunnel would seldom stand without being timbered, and a fissured rock would almost certainly be loosened, and cavities formed, by the operation of blasting or otherwise, so that it would be difficult, if not impossible, to pack the space watertight between the top of the arch and the roof. Where the rock was of a doubtful character, outlet tunnels had been successfully carried out by laying bare a considerable portion at the inner end, and filling up with puddle the space at the side and over the arch. One of the most favourable conditions for a culvert was,

Mr. Jervis. where the point of intersection with the puddle trench was on solid rock, or where the trench had been filled to a moderate depth with strong Portland cement concrete. In such a case a properly prepared trench for a culvert under the embankment, as the Author justly remarked, was constructed in the light of day, and the culvert could be thoroughly inspected, and any scamping be readily detected, either of material or of workmanship. With reference to the material to be used, brickwork in cement had advantages which the best ashlar did not possess, in being more readily handled; additional rings could also be added to resist the increased pressure under the centre of the embankment; and the whole arch, cased in a thick body of Portland cement concrete, would form a piece of rigid work, as it undoubtedly should be; and any risk from the settlement of the embankment might be reduced to a minimum, if the banking was carefully executed in thin layers 6 inches in thickness, tipped from and thoroughly consolidated by dobbin carts. The possibility of the culvert being fractured by the movement of the puddle in the trench longitudinally and transversely was a contingency which could, in most instances, be averted, by having the puddle properly soured and worked before being put in place, and when tipped brought up regularly and in level layers. Pipe outlets laid under embankments had in some instances given cause for serious apprehension, but it was a question, where opinions differed, if they deserved all the reprobation they had received. Failures might have been caused in certain circumstances through defective workmanship, or by placing the valves on the outer ends, thereby subjecting the pipes to shocks and strains, endangering not only themselves but the embankments, and it was an arrangement which could not be too severely disapproved of. Many extensive reservoirs, which had pipe outlets under the embankments with double sluice valves placed at the inner end, and worked from an upstand, had served their purpose satisfactorily, and experience showed that in particular situations they might be adopted with safety.

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25 November, 1879.

JOHN FREDERIC BATEMAN, F.R.SS.L. & E., President, in the Chair.

The discussion upon Mr. Wood's Paper on "Tunnel Outlets from Storage Reservoirs" occupied the whole evening.

2 December, 1879.

WILLIAM HENRY BARLOW, F.R.S., Vice-President, in the Chair.

The following Candidates were balloted for and duly elected as:—

Members.

Antonio Paulo de Mello Barretto.
Patrick Moir Barnett.
James Richard Bell.
George Richard Clark.
Charles Fouracres.
Talbot Hamilton.
Joseph Hindle.
Henry Walter Hudson.
John Kraft.
Henry Coathupe Mais.
Robert Riddell.
William Scott.
William Henry Spalding.

Associate Members.

Edward Hall Allies.
Redmond John Brough.
James Samuel Brown, Stud. Inst. C.E.
Robert Francis Bullen.
George Chamier.
William Bell Dawson, M.A., Stud. Inst. C.E.
John Dickson, Jun., Stud. Inst. C.E.
Bennett Fitch.
Sydney Stewart Grant.
Henry Hawes.
Herbert Edward Horace Hayes.
Brierley Denham Healey.
George Frederic Hammersley Heenan.
John Home Home.
John Charles Johnston.
Edgar Chichester Jones.
Frederick Edward Linging.
Donald Macfarlane, Stud. Inst. C.E.
Thomas May.
Richard Liron Mestayer.
William Henry Morrow.
Joseph William Parry, Stud. Inst. C.E.
John Paterson.
James Ponsford.
John Price, Jun., Stud. Inst. C.E.
Archibald Colin Campbell Rogers.
Fred Simpson, Stud. Inst. C.E.
John Godfree Single.
Alfred Singleton.
Thomas Smith.
Francis Henry Trevithick.
Claude Vincent, Stud. Inst. C.E.
Robert Walker.
Charles Palmer Whitcombe.
Robert Alfred Wilkinson.

Associates.

Ralph Rhenius Evans Brockman, *Capt.* R.E.
Arthur Edward Guest.
Henry Geffcken Kunhardt, *Lieut.* R.E.
Arthur Charles Lucas.
George Newmarch, *Lieut.-Col.* R.E.

(*Paper No. 1643.*)

"The Passenger Steamers of the Thames, the Mersey, and the Clyde."

By WILLIAM CARSON, M. Inst. C.E.

So many millions of persons in this country are dependent in some degree for their means of locomotion on light draught passenger steamers—the omnibuses of the rivers—that the character of the vessels employed and the conditions of their employment may, it is thought, be profitably discussed by the Institution of Civil Engineers. An accident, unparalleled as regards the loss of life which resulted from it, recently attracted public attention, and aroused a considerable feeling of distrust. This lamentable circumstance may well be taken advantage of to consider whether that distrust was well founded, and to indicate the conditions of safety which ought to be recognised by, and may reasonably be expected from, those to whose care large numbers of persons entrust themselves.

The object of this Paper is to describe the River Services of the Thames, the Mersey, and the Clyde, where the huge populations grouped around them are, from the circumstances of their position, dependent upon easy water communication, and where the bulk of the traffic by light-draught passenger steamers in Great Britain is carried. The conditions are different in the examples chosen, and each port has adopted a practice almost necessarily independent of the experience of the others.

On the Thames above bridge, where short distances are traversed, small vessels of moderate speed and light draught, possessing great steerage power and well under engine control, are used, and appear to be well adapted to deal with the traffic of a restricted and crowded smooth-water area. Under such conditions great strength of hull would defeat its object. Great handiness is necessary, and when a choice must be made between strength to resist the force of collisions, and handiness to avoid them, in the latter quality lies the greater probability of safety.

The Thames below bridge presents different circumstances. Longer distances, still within smooth water limits, have to be traversed, requiring higher speed, and, from the comparative

infrequency of the service, large carrying power. Here, again, the consideration of strength as compared with handiness arises. High speeds and large carrying power lead to the employment of long vessels. Long vessels, not being so amenable to steerage, must, in close quarters, chiefly rely upon their ability to check or reverse their way. This augments their risks, and would seem to demand a corresponding increase in the strength of the vessels. There are, however, compensations arising from the difference in the character of the general traffic above and below bridge; for, while assailants are to be looked for from all quarters above bridge, the risks below bridge are to a considerable extent those resulting from the movements of an end-on river traffic, which vessels under good engine control are tolerably well able to avoid.

It must be remembered that the steam boat services of the Thames have this important disadvantage, as compared with those of the Mersey and the Clyde, viz.: that all the lines compete with railway and omnibus routes. In suggesting their possible shortcomings, it ought to be considered that in wet or foggy weather, and from a hundred other chances, the passengers whose carriage is provided for may be intercepted, and that the loss of traffic so arising can scarcely be averted by the conditions of the management, or by superiority in the construction of the vessels. Further, considering that water carriage does not command equal fares with land carriage where they compete, it is reasonable to conclude, that while the utmost precautions ought to be taken to ensure safety, the quality of the accommodation must not be expected to surpass the dividend-earning capabilities of the traffic. At Liverpool the service is carried on at the mouth of an open estuary. It accommodates those who have no option as to route, and who must cross to and from their homes or places of business at least daily, no matter how severe may be the gale or how dense the fog. The traffic is concentrated on the Lancashire side at the narrowest part of the estuary, and about the centre of the town, where the great Landing Stage, an unequalled work of the kind, has been constructed by the Mersey Docks and Harbour Board. Here are provided convenient and ample facilities for passenger access to the river, and also an approach for carts and general street traffic by a continuous roadway, which is always available, notwithstanding that an extreme rise of 32 feet had to be considered in the determination of the design. From the great Landing Stage the ferry routes diverge to points on the Cheshire side 6 miles up the river and 3½ miles down the stream, at its mouth; while the

bulk of the passengers cross almost directly over to Woodside and Seacombe, a distance of less than 2,000 yards.

The circumstances are in other respects peculiar. Its broad and unprotected entrance renders the Mersey so extremely turbulent during heavy gales, that towards its mouth safe landing is impossible, and even in the higher reaches is difficult, while the tide at extreme range produces at the seat of the ferry traffic a current of 6½ knots an hour. Then, nearly all the traffic is conducted across stream, adding greatly to the risks of navigation because of the usually crowded state of the roadstead—a roadstead without anchorage regulations, and where vessels bring up in any position which suits their convenience. It will be obvious that on so rapid a stream, with possible uncertainty as to what may lie in the course, the conduct of a traffic of over twenty million passengers a year, during all weathers, and especially during fogs, is one which demands the utmost care and circumspection, both in respect to the vessels and to the staff employed.

The vessels fairly conform to the conditions. Short runs do not require high speeds, so that with similar engine power heavier vessels, suited to cope with bad weather and difficult landings, are driven at a low speed compared with those on the Thames and Clyde; and with greater safety, not only from their lower speed, but also, as speed may be somewhat neglected, because their increased weight affords more strength and an opportunity for a better disposition of parts. Sponsons extending all round, built up as a part of the ship's sides, or of heavy overhanging timber and ironwork, are necessary for the wear and tear of vessels which must bring up at a landing-place every five minutes, often in a heavy sea; and they afford an important protection against damage in ordinary collisions, especially when constructed, as they ought to be, as a component part of the hulls. Then, large deck area being required, and the lengths being limited from obvious considerations, an extreme proportion of beam to length (in some instances more than 1 to 5) is unavoidable, and their large displacement is well utilised, in the highest class of vessels, by a division of the power between two pairs of engines, each pair acting independently on a single paddle-wheel. Perfect steerage control is in this way secured under the everyday occurrence, when, as regards an alteration in direction, seconds may make the difference between the peril or the safety of the passengers.

The character of the Clyde river traffic is somewhat similar to that of the lower Thames. Long journeys, within partially smooth

water limits, are performed at high speeds; and while designers are uncontrolled, except by the consideration of speed, in the proportions of the vessels, a liberal allowance of power can be afforded to secure it, because of the higher scale of fares which the service commands. Most of the stations are accessible only by water, and chiefly on this account the river service is altogether superior to that of the Thames, where, as has been pointed out, competition by land carriage affects every station. The fierce tidal currents of the Thames and the Mersey, and the consequent difficulties of navigation, do not occur on the sluggish Clyde, where the risks are, almost exclusively, those arising from an end-on traffic; handiness as regards engine control is the best qualification to avert them. The large power employed, and the comparatively light weights, in proportion to the power which have to be moved, ensure the fulfilment of this condition; while the assistance which ample rudder area, controlled by steam steering apparatus affords, is also usually secured. Heavy sponsons are unnecessary for the service, and would materially affect speeds. The fares fix the paying engine power, and the speeds will be higher or lower according to the weight to be driven.

Some examples of the vessels constructed for these river services may here be given.

One of the latest of the above-bridge Thames boats was built of iron by Messrs. Samuda and Co. (Plate 6, Fig. 1). She is double breasted, 90 feet long, 13½ feet beam, 6½ feet deep, 80 tons B. M., and is capable of being driven at a speed of 10 miles an hour in slack water, on a draught of 2½ feet, representing a displacement of 42 tons. The propelling power is derived from a pair of common condensing oscillating engines, with cylinders 21½ inches in diameter, and 2 feet stroke, working at a boiler pressure of 25 lbs. The feathering paddle-wheels have an effective diameter of 10 feet. Two bulkheads forward, and one aft of the engine space, divide the vessel into four tolerably equal watertight compartments. Short sponsons protect the paddle-boxes, and form landing platforms for the gangways, but they are of too slight a character to afford much protection to the hulls, except against the chafe of the landing places; no protection of the ends is attempted. The passenger cabins are below deck, of a clear height of 5¾ feet. Openings in the vessel's sides admit light. Proper ventilation does not appear to have been contemplated, and the means of access are cramped and inconvenient. In such vessels the bulkhead divisions are not sufficient for safety, doubtless because the designers had principally the cabin accommodation in view.

Now, as external protection for the hulls is scarcely possible, having regard to the important consideration of weight, an efficient division by bulkheads is all the more necessary; safety, not comfort, ought to be the chief aim, and it is thought that in neither of these respects are the above-bridge vessels satisfactory. No doubt their designers were somewhat hampered by the small dimensions of the boats, and the limited head room under bridges. For these reasons, and also on account of its wind draft, the type of vessel with the saloon on deck is unsuitable. But, as is sometimes done, if all cabins were constructed under a break or poop at each end, so that light and ventilation could be obtained, with roomy cabin spaces; and if a middle-line bulkhead, of such height that alteration in trim, consequent upon a side compartment being filled, would not submerge it, were fitted between water-tight transverse bulkheads at each end of the cabins, both comfort and safety would be better secured. The access would be easy; a short stair of four or five steps would be divided halfway down by the longitudinal bulkhead, and so lead into either division of the cabins. In this way, without any great increase in weight, eight effective watertight compartments might be provided.

In some of the later Woolwich boats the cabins have been constructed under breaks. A recent example was built of iron by Messrs. Westwood and Baillie (Plate 6, Fig. 2). She is single breasted, 131 feet long, 16 feet beam, 7½ feet deep, and is capable of being propelled at a speed of 12 miles an hour in slack water, on a draught of 3½ feet, representing a displacement of 86 tons, of which 29 tons are taken up by the machinery and the water in the boiler. She is provided with a pair of oscillating engines of the usual type, having cylinders 23½ inches in diameter, and with 2½ feet stroke, working at a pressure of 36 lbs. in the boiler. The feathering paddle wheels have an effective diameter of 10 feet 4 inches. The hull is as unprotected externally as the above-bridge boat already described, and she is divided into four water-tight spaces. The passenger shelter, under a break aft of a height of 1 foot 6 inches above the main deck, is superior to that of the former vessel; and so far comfort has been considered, but it does not appear that greater safety has been attained.

Danger to such a vessel would arise if either of the end compartments were so injured as to become filled with water. Upon the submergence of the deck the water would, no doubt, find its way through the hatchways and engine openings into the

middle space, and she would go down. Damage to the middle compartment would rarely become dangerous, unless from the flow of water into the ends through open side lights (should immersion proceed so far), or from the vessel losing her trim.

The Thames excursion boats, of the "Albert Edward" and "Alexandra" class, are similar to the Clyde vessels which will be subsequently described, as is also the work for which they are employed.

The ferry boats used on the Mersey differ as much as their services from those of the Thames and the Clyde. They have the bow and stern alike, with a rudder at each end, and are capable of being propelled in either direction. Of the cross-river boats, perhaps the finest ferry steamers in the world are the paddle-wheel vessels now used for the passenger traffic between Liverpool and Birkenhead by the Woodside Ferry, amounting to about ten million persons annually. The circumstances of the traffic are favourable, and they have been fully taken advantage of by the corporation of Birkenhead, who are the proprietors of the ferry. No great speed is necessary, the passage being scarcely more than 2,000 yards across. The traffic receipts, in penny fares, amount to £45,000 a year. This sum is earned by five vessels, three of which make trips at intervals of ten minutes from either side, keeping the communication open with comfort and regularity by night and day under all conditions of weather.

A description of the "Claughton" will serve for the five ships so employed (Plate 6, Figs. 3 to 10). This vessel is double breasted, was built by Messrs. D. and W. Henderson and Co. in 1876, and is 150 feet long, 31 feet breadth of beam, and 13 feet deep from keel to gunwale. A pair of diagonal direct-acting engines is fitted to each paddle-wheel; the two pairs being of a combined indicated HP. of 635, working at a boiler pressure of 40 lbs. per superficial inch, and able to propel the vessel on a draught of 7 feet 8 inches, equal to a displacement of 630 tons, at a speed of 9 knots an hour. Six transverse watertight bulkheads divide the vessel into seven compartments, the engines being placed in the midship compartment, and the boilers each in separate water-tight spaces forward and aft of the engines. The other bulkheads are so arranged as to secure tolerably equal spaces towards the ends of the vessel. In addition to these transverse bulkheads two longitudinal bulkheads extend from end to end, except through the engine room, at a mean width of 10 feet from the middle line. As an additional precaution in case of collision, the sponsons, which are of the full width of the paddle boxes, forming a deck platform

49 feet broad, are constructed as a part of the body of the vessel, the frames and shell plating being carried out to the full breadth. An overhang of 6 to 9 feet from the ship's sides, equal in strength to them, is thus secured; and this overhang must be cut through, in the event of collision, before the vessel could incur serious damage. Brown Brothers' hydraulic machinery is applied to the starting gear of the engines, and also for steering; and there is telegraphic communication between the bridge and the engine room. The passenger accommodation is afforded in a deck saloon about 120 feet long and 17 feet broad, and its top forms a promenade. Smaller cabins are arranged below deck at each end for smokers and the crew. The builder's measurement of the "Claughton" is 672 tons, her register tonnage is 149 tons, and she is licensed by the Board of Trade for fifteen hundred and ninety-eight passengers upon the service for which she is employed. Here, probably, is as good a vessel of her class as human skill and foresight can provide, reflecting much credit on her designers and builders. Every precaution which long experience could suggest has been taken; and, although vessels for ferry purposes must necessarily conform to the differences in the stations for which they are intended, yet the "Claughton" is, no doubt, the type which ought to be kept in view in designing them.

The "Heatherbell," used for the lower and more exposed river service, is a flush-decked vessel, with the cabins below deck (Plate 6, Figs. 11, 12 and 13). She is 160 feet long, 21 feet beam, and 9½ feet deep, and is able to carry nine hundred passengers, at a speed of 10 knots an hour, with 320 indicated HP., on a draught of 4½ feet, equal to a displacement of 280 tons. The cabins below deck are 7 feet high, lighted by large side windows, and ventilated through the deck for their entire length. A semi-saloon on deck amidships is 70 feet long, forming a promenade on the top and covering the cabin entrances, and she is divided into seven water-tight compartments by transverse iron bulkheads. Heavy timber sponsons and rubbing pieces extend all round her.

The "Waterlily," a satisfactory example of another type (Plate 6, Figs. 14 and 15), is 140 feet long, 22 feet beam, and 8¾ feet deep. The structure of the hull is extended 2 feet at each side, making her breadth on deck 26 feet, and there are heavy timber sponsons from end to end. This vessel carries eight hundred passengers, on a draught of 4¾ feet, at a speed of 10 knots an hour, with 300 indicated HP., and the displacement at that draught is 267 tons.

A break at each end, of the height of the bulwark rail, forms a promenade deck above, and affords roomy cabin spaces below, well lighted and ventilated by large sliding windows in the sides, and reached by four or five steps from the main deck. The hull is divided by transverse iron bulkheads into nine watertight compartments, and the vessel is fitted with Bremme's steam steering and anchor raising gear.

It will be observed that, in the construction of the Mersey boats, safety has been made a consideration of paramount importance. Steering by hydraulic or steam power, and communication by telegraph between the bridge and engine-room, are adopted in the best vessels.

Of the highest class of Clyde passenger steamers are the "Columba," built of steel, by Messrs. J. and G. Thomson, in 1878, for the mail route from Glasgow to Ardrishaig, and the "Lord of the Isles," an iron vessel, built in 1877 by Messrs. D. and W. Henderson and Co. (the builders of the ferry steamer "Claughton," already described), for the service from Glasgow to Inverary.

The "Lord of the Isles" is licensed for thirteen hundred and sixty-nine passengers (Plate 7, Figs. 1 to 5). This vessel is 246 feet long, 24 feet beam, and 9 feet deep from the top of the keel to the gunwale. The propelling power is a pair of diagonal oscillating engines, with feathering paddle-wheels of 19½ feet effective diameter. The engines develop 1,800 indicated HP., and propel the vessel at a speed of 22 miles an hour, on a draught of 4 feet 5 inches, representing a total displacement of 420 tons, of which the weight of the machinery and water in the boilers is 160 tons. There are four transverse water-tight bulkheads. The exigencies of the cabin accommodation for passengers upon so long a run as 80 miles appear to have involved this comparatively imperfect division. Bow, McLachlan and Co.'s steam steering gear is used, and Chadburn and Son's telegraphs. The machinery is arranged in the midship compartment. The cylinders are 46 inches in diameter, with a stroke of 5 feet 6 inches, and are supplied with steam by two multitubular haystack boilers, one forward and one aft, loaded to a pressure of 50 lbs. per superficial inch. On the main deck there are two saloons, and on the top of them a promenade deck, for the full width and 200 feet long, on which is the captain's room and ticket office, with flying bridge from paddle-box to paddle-box. The entrance to the main saloon is by a wide stairway, at the bottom of which is the post office, for receiving letters, newspapers, telegrams, &c. Openings right and left afford ingress to

the main cabin, a lofty and well-ventilated apartment, 50 feet long by 16 feet wide, luxuriously furnished with spring sofas, mirrors, racks for hats, &c., and tables with writing materials for the free use of the passengers. At the after end is a small boudoir and lavatory for ladies and young children. Immediately underneath the main saloon is the dining cabin, 60 feet long by 22 feet wide, reached by a stairway 5 feet 6 inches broad. The floor is laid with narrow polished planks of walnut and oak alternately, and the steps of the stairway are of teak, with india-rubber treads. All round the sides are spring sofas, covered with morocco leather. Revolving chairs enable diners to leave the table without disturbing each other. One hundred passengers can dine at one time, and the decorations are similar in style and completeness to that of the cabin overhead. The saloon and the fore cabin are ventilated by quadripartite vertical shafts, which reach to some height above the promenade deck, and so constructed that effective up and down currents of air are established. There is ample and convenient lavatory accommodation for gentlemen in connection with this dining saloon. The saloon at the fore end is fitted and furnished in a similar way to the after saloon, and the forward dining cabin, 37 feet long by 23 feet wide, is capable of accommodating seventy passengers at a time; the decorations and internal furnishings are similar to those of the after cabin, with a separate pantry, bar, galley, and lavatories, &c. Accommodation for the officers and crew is provided in front of the fore saloon, under the main deck. All the arrangements are of a complete kind; unusual provision has been made for the comfort and convenience of passengers; and with her exceedingly high speed and magnificent accommodation it may be said that the "Lord of the Isles" affords a very favourable example of her class.

The extraordinary growth of the population round the harbour of Glasgow has necessitated the substitution of steam vessels for the ordinary rowing boats which formerly used to ply between the north and south quays, and the extent of the traffic may be inferred from the use of steam power in working it.

The screw passenger boats which have been constructed for the Clyde trustees by their engineers at their own yard, are 49½ feet long, 12½ feet beam, and 4 feet deep, with a draught of water of 2 feet 10 inches when light. They are built in watertight compartments, and are certified for one hundred and twenty passengers. The propelling power is obtained from a pair of high-pressure engines of 6½ nominal HP., the cylinders, 6¼ inches in diameter and

10 inches stroke, being inverted, and set diagonally. As the vessels are intended to progress in either direction, a novel feature has been introduced by fitting a screw propeller at each end, and the result has been satisfactory. The vertical boiler is 8 feet high, and 3 feet 4 inches in diameter, having fifty-eight close-ended hanging tubes in the furnace, each 30 inches long by 2 inches in diameter; and it is loaded to a working pressure of 80 lbs. per superficial inch. In addition to their work as ferry boats they are fitted as fire engines, with one of McFarland's rotary pumps, worked from the main shaft by spur gear, each of the propellers having a disconnecting coupling, which can be thrown out of gear when the fire pump is at work. The engines are so constructed that the boat can be stopped and the fire engine set to work at a moment's notice, or it can both discharge water and run at the same time, either backwards or forwards.

The steamers to be built for the cart and horse traffic have been designed by Messrs. W. Simons and Co., of Renfrew, and are to be propelled by four screws (Plate 7, Figs 6 to 9). The deck is a movable platform working within guides fixed to the vessel, and capable of being raised to the desired height by hydraulic machinery. These vessels are thus independent of any special landing appliances to overcome the rise and fall of tide, and can be adjusted alongside any river wall to receive their cargo. The deck when loaded is lowered down upon the vessel, and upon reaching the opposite quay the deck is again raised, and the carts and horses are driven ashore. This highly ingenious arrangement appears suitable for such a traffic, in protected waters where the tidal range is moderate, and also for crossing docks or landing troops and artillery.

Having described the principal river services, and the vessels engaged upon them, some general remarks may be permitted.

It must be remembered that light-draught passenger boats employed within smooth water limits are not subjected to the strains arising from heavy loads, and the rough treatment of sea-going vessels. The largest of their class, with, for example, a passenger certificate for one thousand persons, will have a displacement of 350 to 400 tons, and the weight of passengers and luggage will not exceed 50 tons, equal perhaps to 6 inches of immersion above that due to the weight of the vessel. It is evident that their proportions and scantlings need not conform to those of sea-going vessels designed to carry up to half as much again as their own weight. The severest strains to which they are subjected probably arise from their engine power; from the concentration of the weights

of the engines and boilers, which, in order to economise space, are usually placed in a small compass in the middle of the vessels; and from the weights of the fine ends, which do not supply displacement to support themselves. Being always waterborne along their whole length, it may be said that the conditions of a girder cannot be strictly applied to them, and that the principal considerations are the due distribution of the weights of the machinery over the floor of the displacement-earning portion, and the provision of sufficient top section to support the weight of the partially unsupported ends. The strains from the load and propelling power appear to be of so moderate a character, that they can be well taken up without such an increase in the total weight as would unfit the vessels for their special work, which particularly demands speed and a light immersion.

As regards their ultimate strength, it is important to notice that many vessels built for river service of extreme proportions of length to depth, and of very light scantling, have accomplished long and stormy voyages successfully, both under steam and under sail. One of the famous "Iona" class, with a depth of $\frac{1}{25}$ of the length, crossed the Atlantic during the American Civil War, in the autumn. A similar vessel, the "Lizzie," performed the same voyage under even severer circumstances; and another, the "Rothesay Castle," originally built for the Clyde river service, has been employed for some years in carrying passengers on the rough and exposed station between Arran and Ardrossan. The great strength of even the lightest iron structures is well shown by the work that these and other river craft have performed—work so far beyond that for which they were designed, that their perfect seaworthiness for their proper duty is beyond question. It is therefore evident that from collision alone need danger be apprehended, and its results anticipated in their design.

In sea-going vessels this is attempted by a division by bulkheads, which are intended to limit the effects of injury, or at least to keep the vessels afloat long enough to enable those on board to escape by the boats.

In river craft, however, boats are not compulsorily carried. The vessels, it is thought, are likely to be always close enough to the shore to be run aground in the event of injury; and further, the incumbrance of boats would unduly interfere with the conduct of their business. Thus bulkheads are if possible more necessary in river craft than in sea-going vessels; and though, as has been seen, they are usually fitted, there is no obligation to do so, and no rule

for the proportion of capacity of the compartments to the total capacity of the vessels.

Owing to the exigencies of their trades, and the desire of providing large passenger spaces below deck, it is feared that sufficient attention is not always given to a due subdivision, so as to secure a reasonable chance of safety in collision. It might be, perhaps, better to say a chance of safety in such force of collision as may be reasonably expected. Collisions do not arise from *malice prepense;* and when they do occur, there is generally sufficient presence of mind in the commanders to enable them to mitigate their effects, either by an alteration in the direction in which the blow is given or received, or by an abatement of speed. Surely such mitigation may as fairly be expected from the conduct of the commanders of the vessels involved, as from the strength of the structures themselves to withstand the force of the blow. If this presence of mind is not to be counted upon, it may be said that no vessel has been built which can, in such circumstances, afford much chance of safety to those on board.

It is important, in determining the division of small vessels by bulkheads, to consider what would be their probable behaviour upon the withdrawal of so much displacement and stability as would take place if a compartment were filled with water, while the full complement of passengers was on board; and this consideration ought to determine the dimensions of the compartments in the first instance. Modifications may have to be made to meet special requirements, but the original division ought to be adhered to as nearly as possible, even at the risk of complaints about the smaller cabin spaces below deck.

The superiority of vessels having their passenger accommodation principally on deck, both in safety and comfort, will be apparent. Where deck saloons do not render the vessels unsuitable to their stations on account of wind draft, and when the vessels are of sufficient size to allow of their construction without being overburdened, a perfect division of the hull may be made, without any other consideration than that of safety. But when the cabin spaces must be below deck, the advantages to be gained from longitudinal bulkheads are worth consideration.

The Author has attempted to show that in designing river craft the points of importance for safety are: (1) their effective division by bulkheads; (2) their defence, especially when employed in cross-river traffic, by overhanging sponsons; and (3) their being well under engine control.

These having been satisfied, the means at the disposal of the

commanders, by steering apparatus and communication with the engine-room, for the complete control of the ship must not be overlooked. The wheel should be amidships, and it is strongly urged that steam or water power ought to be employed for the steerage of all vessels of more than 120 feet in length when engaged in river passenger traffic. A steam steering apparatus might be utilised for other work of the ship, *e.g.*, as an anchor or cargo winch, with a corresponding saving of labour to the crew.

A perfect mechanical communication between the master and the engineer is highly desirable. It is believed that on the Thames alone the antiquated mode of "passing the word" by a call-boy is still adhered to. On the Mersey and the Clyde a mechanical telegraph is an important part of a river steamer's outfit. The form most in use on the Mersey, which is that of Chadburn and Sons, is particularly suitable for double-breasted vessels. A handle fixed on each paddle-box, capable of motion ahead and astern, is moved by the commander in the direction in which it is required that the vessel shall proceed. No consideration of the conventional terms "ahead" or "astern" is needed; the direction in which the handle is moved is the direction in which the engineer, on a corresponding dial, receives the order to move his engines; the chances of error in the orders are minimized, and no lighted dial is necessary at night; the handle on the bridge (standing upright when no motion of the engines is desired), and the dial, with finger and bell, worked by an endless chain in the engine-room, comprise the whole of this inexpensive apparatus.

The Board of Trade does not interfere in regard to these matters; but the public would probably gain by a hard and fast rule for division by bulkheads. The Board does insist that twenty-four life-buoys shall form part of the equipment of river craft; and they might well proceed a little further. All deck seats ought to be fitted loose, and rendered equally buoyant, foot for foot, with regulation life-buoys; thus an increased chance of safety would be secured in the last resort—a not unreasonable requirement from the owners of vessels, which carry so large an amount of human life in proportion to their tonnage as to render any adequate provision of boats impossible.

It is obvious that engineers and shipbuilders will always construct vessels to owners' requirements. This is a matter of money. Owners having such heavy responsibilities are generally alive to their duty to the public in the due and proper equipment of their vessels. Above every other consideration is the skilfulness or otherwise of

those in charge of the vessels. The public must not be allowed to expect immunity from risks at the hands of the shipbuilder or engineer. In default of skill in the commanders, the precautions of thoughtful construction will not avail. If the commanders are incompetent, it is to the managers, and not to the constructors, that the public must look for assistance.

The Paper is illustrated by several drawings, from which Plates 6 and 7 have been compiled.

Discussion.

arson. Mr. CARSON said the subject of the Paper had been suggested by the unhappy accident to the "Princess Alice," and it had been approached rather from a public than from a technical point of view. The question was, whether such craft were safe or unsafe? and it had been thought desirable that a Paper should be prepared with a view of eliciting an expression of opinion on that subject.

lackie. Mr. S. J. MACKIE asked permission to say a few words, having taken for more than twelve years a great deal of interest in the construction of vessels with regard to their safety. When it was considered that river vessels were specially designed for carrying living freights, and ought therefore above all others to be protected, it would be seen that it was a matter of the utmost importance that they should be efficiently constructed. If any engineer or naval architect would conscientiously study the design of such a vessel as the "Princess Alice," or the "Albert Edward," or vessels of that type, carrying five hundred passengers and upwards, he would see that they were utterly unfitted for the service they were intended to perform. The engine space and the boiler space occupied the whole of the centre—a space which, above all others, should be devoted to the buoyancy of the vessel; and there was a length of from 60 to 70 feet open from one end to the other, and defended against the ingress of water by plates which were as worthless as brown paper, being only $\frac{5}{16}$ inch in thickness. Considering the dead weight in the centre and the buoyancy of the two ends, separated by bulkheads, if the central portion were pierced, nothing could save the vessel from being rent in twain, and the engines would not be able to run the vessel even the shortest distance ashore. The principle which he had for many years endeavoured to carry out, at a considerable expenditure of time and money, had been that of constructing vessels upon a system which would involve little, if any, greater weight of iron than that hitherto adopted. He would utilise the saloon, or central part of the vessel, by carrying the saloon walls down to the bottom; in other words, using longitudinal girders, or bulkheads, one on each side, leaving the central space perfectly free for the service of the ship. In case of a collision the general buoyancy of the ship would not be affected. By putting the boilers abaft and forward, and the engines in the centre, dividing them by bulkheads, the vessel would be rendered secure. The iron could be disposed in a better manner than by adhering to the old form of ship-building, and the total weight of the ship

would not be more than by the system hitherto adopted. The chief Mr. Mack practical objection to the system was, that it cost about 5 per cent. more than in the case of an ordinary vessel. The method had been approved by builders of the highest eminence. The officers of the Board of Trade had also unofficially examined it, and he desired to say that he was quite satisfied with the treatment he had received from those gentlemen. Unfortunately they had no one to support them in regard to matters of safety; there were many adverse interests, and, unless a public movement were initiated by this or some other Institution, he did not think the officers were powerful enough to do that service to the country which he believed it was their desire to render. The Author had credited Messrs. Henderson with the design of a vessel with longitudinal girders. Mr. Mackie had designed a passenger steamer for the Thames, in 1870, under this system.[1] It would be seen that the longitudinal girder system was thoroughly carried out according to the principle he had then patented.

Mr. T. B. Winter said that, some years ago, the Government of Mr. Win India, desiring to improve the navigation of the shallow and rapid rivers in that country, appointed a commission, of which he had the honour to be a member, to visit the different European rivers with a view of gathering information on the navigation and the class of vessels used. In the course of their investigation they visited the Danube, the Rhone, and other rivers of importance, including the Clyde. The navigation of the Danube was, in many respects, similar to that of the Clyde. The risks were mainly end-on risks; the amount of traffic was not considerable, and, generally speaking, the vessels used were similar to those adopted on the Clyde. The draught of water was about 4 feet, and the speed was from 11 to 16 knots an hour, according to the class of service. There were, however, some parts of the Danube, mainly the "Irongates," where a specific class of vessels was required. The "Irongates" was a name given to rapids running, according to the season of the year, from 7 to 10 miles an hour. The depth varied at different seasons, but during summer it was little more than 2½ feet. The vessels which, at the time of their visit, were employed upon the service, were plying for a few miles above and below the rapids. Their draught was only 1 foot 3 inches; their length 150 feet; their breadth 20 feet; the engines were 40 HP., driving two distinct pairs of paddle-wheels, each pair being actuated by a distinct pair of engines. The result

[1] *Vide* "The Illustrated London News," December 7, 1872.

Winter. was certainly very good. The boats went through the extremely rapid currents with great regularity; accidents were extremely rare, and the service was admirably performed. He believed, however, that the river was now so far improved that those vessels were not needed. These boats with four paddle-wheels answered their purpose so admirably that the Company, who owned them at the time to which he alluded, had in consequence put upon the river two other vessels of much larger dimensions, also with four paddle-wheels, for the navigation of the deeper portions of the river; but he believed they were not found to answer for the ordinary navigation: they were costly, and the same amount of fuel did not produce the same result as to carrying capacity or speed. There was another peculiar class of vessel on the Danube, which was used for towing. The draught of water was about 4 feet, and the vessels were propelled, as in the case of American vessels, by over-head beam engines, driving paddle-wheels about 40 feet in diameter. They were about 220 feet long, 40 feet beam, and 80 feet wide over the paddle-boxes. Their peculiarity was, that they had no "run" in the ordinary sense, they were the same breadth abaft as amidships, the after body being shelved up to the load line much like a Thames barge. The bow was of ordinary form but very bluff, the bottom perfectly flat. The vessels were most efficient, and he knew one of them which towed sixteen barges, each loaded with 250 tons, at a speed of 3 miles an hour against a 2-mile current. The effective power of the vessel seemed to be enormous, and the work was done most economically. These were the principal vessels of interest on the Danube.

On the Rhone, a much more rapid river, flowing from 5 to 6 miles an hour, there were some extraordinary vessels. They were built first about 130 or 150 feet in length and 18 or 20 feet beam; but as trade increased, it was suggested that they might be cut and lengthened, which had been done over and over again. The longest vessel which he saw at work was 475 feet long by 19½ feet beam, drawing 4 feet of water; she carried an enormous amount of goods, but was extremely unsightly. The competition of the railway had driven those vessels off the river, and he did not think many of them were now running.

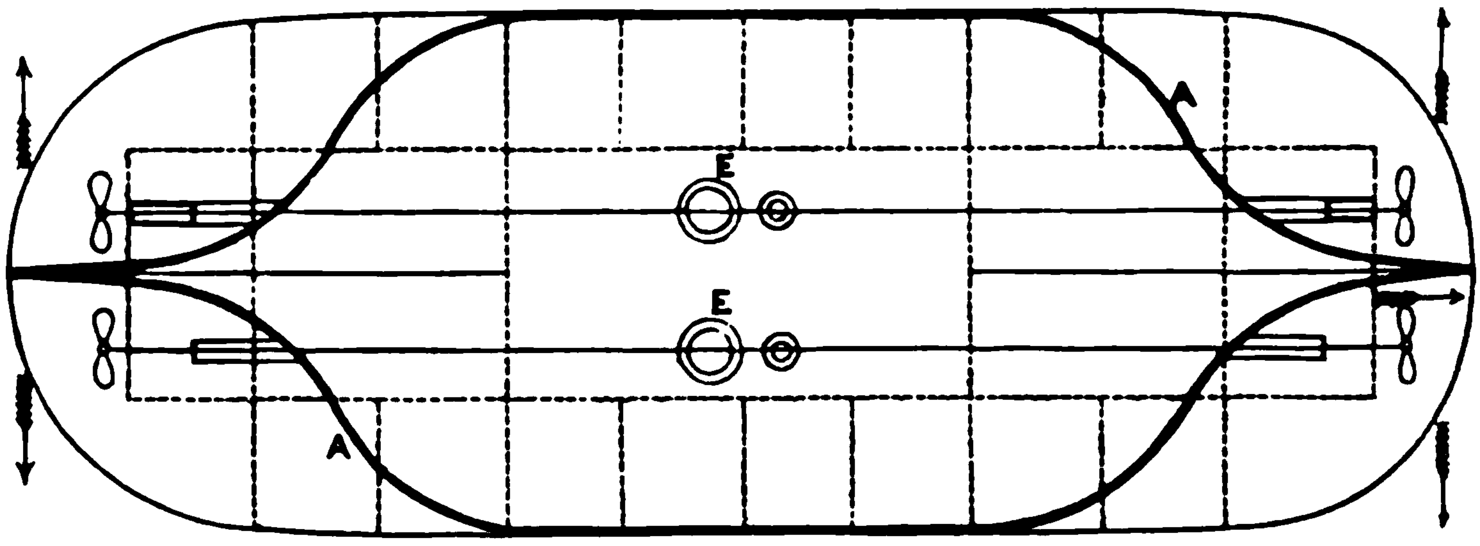
As the result of their investigation the Commissioners were led to advise, for the use of Indian rivers, a different class of vessel from that which had been previously adopted. They found, from experience on the Danube and on the Rhone, that great dimensions did not, in a material degree, interfere with the success of the navigation.

Indeed, lengths and breadths seemed to be of little importance, one vessel being nearly as handy as another. The Indian rivers differed from those of Europe, inasmuch as although some were as rapid, the effective depth was much less. The bottom was almost always sand, which, from the rapidity of the current, was constantly being shifted, and sand-banks were sometimes thrown up in a night where there had been a deep channel the day before; consequently, vessels were frequently running aground and getting into every sort of trouble. The vessels so often ran on to the sand-banks that it was necessary to adopt some means of preventing their cutting too deep into them. The Commissioners suggested that future vessels should be made of a spoon shape at both ends, so that in case of their running on to a bank either ahead or astern they would shelve themselves up on to it, and so be more easily got afloat again. One of those vessels, built from his drawings and under his instructions, was put together on the Mersey and tried there. It was a paddle boat 239 feet in length by 38 feet beam, and 2 feet working draught, with about 400 effective HP. The vessel was built by Messrs. Laird, and the result of the trial was very successful. When put in competition with a tugboat of the Mersey, although of so light a draught, there was no doubt that her towing capacity was greater than that of the tug. She, with several similar vessels, had since done good service in India. The Commissioners also recommended, as an experiment, the construction of a very large vessel, 375 feet long by 46 feet beam, and 74 feet wide over the paddle boxes; draught, 2 feet, and to go at a speed of 10 miles an hour. This vessel was put together, and tested on the Thames with considerable success; but notwithstanding the stipulation that she should never be exposed to a sea swell she was rebuilt in India, in such a position as to necessitate a sea passage before reaching her station; the consequence was that she broke her back, and the experiment was lost. If the vessel had been worked on the river, he believed she would have done good service. She could carry a regiment with ordinary baggage on 2 feet draught. The Government, however, now subsidised railways, and did not need a flotilla. Indeed, considering the difficulties of Indian river navigation, and the great cost of the boats required for the purpose, he was not surprised to find river navigation was being largely superseded by other means of transit. Mr. Winter.

Mr. James Taylor (Birkenhead) desired to bring before the Institution a novel construction of ferry-boat used at Woodside. For sixteen years he had been connected with the Ferry Committee, Mr. Taylor.

Taylor. and had taken great interest in the working of the boats both for passenger and goods traffic. For the last two years he had been chairman of the committee of the late Birkenhead Improvement Commissioners, and he had made it a particular point to endeavour to arrive at a mode of construction for a ferry steamer that would be safe and handily used on the waters of the Mersey. The model exhibited represented the "Oxton," a boat 130 feet long by 45 feet beam; draught, from 7 feet 8 inches, with a free board of about 6 feet 9 inches; constructed to carry carts, carriages, horses, cattle, and goods across the river, between Liverpool and Birkenhead on the Woodside Ferry.

Fig. 1.

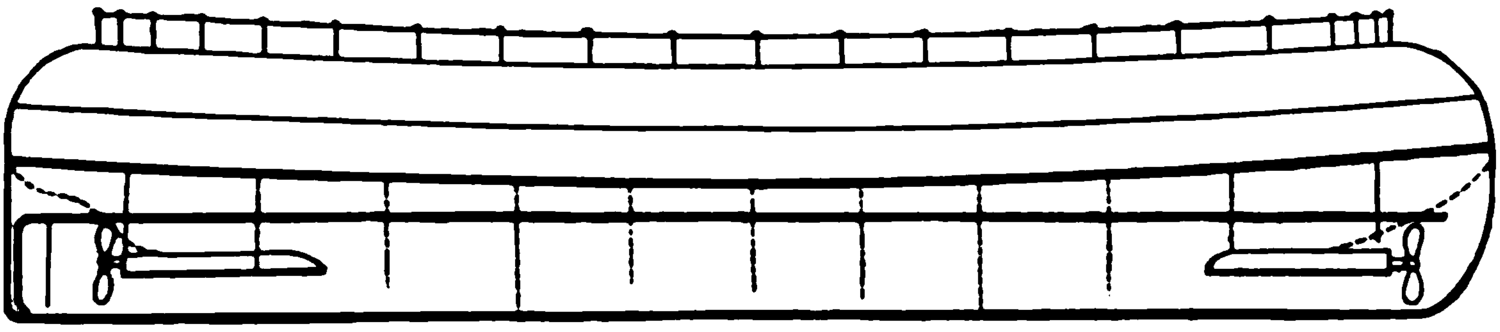


Plan.

In Fig. 1 A A represented the skin of the vessel, where the propeller shafts passed through from the engine E E inside to the screws outside. When going straight ahead the screws being made right and left-handed required the engines to be driven in opposite directions; but when required to spring from her berth, the engines went in opposite directions, whilst the screws operated upon the water also in opposite ways, and turned the vessel round as on a pivot. The dimensions were extraordinary as contrasted with those of the vessels previously described. She was built with two pairs of engines; one pair on one side driving one propeller forward and one aft, and the same on the other side. That was for the purpose of taking the place of the paddles with fixed floats as in the vessels of the Claughton type, having a pair of engines to each paddle-wheel. The vessel had been working since July, 1879, with great success. On the trial trip, the gentleman who had the handling of her, apart from the contractors, dropped a buoy, when she was in a state of rest, at each bow, the vessel being double-ended. Putting the vessel in motion he turned her round in her own length in about four minutes. He then took a run back and came up to the first buoy at full speed, reversed

the engines, and she pulled up within a distance of about her own Mr. Tayl
length. To be able to pull up a vessel of this class in so short a distance was a matter of great importance on the river Mersey, which was often crowded with vessels, and where they were exposed to dense fogs. The engines were compound cylinders, 19 inches and 34 inches in diameter, with a stroke of 24 inches. The two pairs indicated at the trial about 570 HP. At first she did not attain the speed contracted for, but that was on account of the propellers being four-bladed, too broad, and having too coarse a pitch. They were then replaced by others having three blades, and the speed was now equal to that of any of their other paddle steamers. The builders, Messrs. Simons & Co., of Renfrew, had informed him

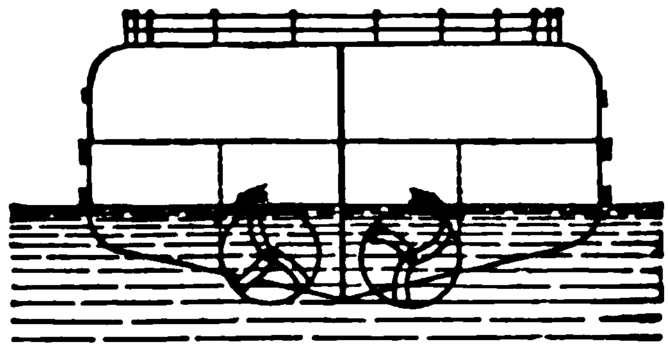
FIG. 2.



Side elevation.

FIG. 3.

Promenade deck.



that they could undertake, on that bottom, 130 feet by 45 feet beam, as in Figs. 2 and 3, to construct a vessel with saloon and other accommodation capable of carring fifteen hundred passengers. With regard to the consumption of coal, the Claughton class took about 10½ cwt. per hour, but the vessel he had described only consumed 4½ cwt.; so that if she could carry as many passengers, the saving of fuel would be very considerable. He also exhibited another model showing the construction of a passenger boat, furnished to him by the contractors, Messrs. W. Simons & Co., in which there was an arrangement of water-tight compartments immediately within the hull, as in dotted lines in Fig. 1. He believed that the desired end of safety would thereby to a considerable extent be attained. The question of having four propellers was no doubt open to discussion. He was not

Mr. Taylor. very familiar with naval work, but, as an engineer, he thought that the two forward propellers entering the water freely took a better grip and would do most duty. Some persons had said that it might be objectionable to send the water against the bow of the boat with forward propellers, but the lines were such that the water coming from the propellers was sent underneath. The after propellers might perhaps be constructed of a rather coarser pitch than the forward propellers, and in that way he believed a better speed could be attained. He might mention that in the "Oxton" there was one bulkhead running fore and aft over the keel. Such had been the success of the boat, that the Birkenhead Corporation had resolved to build another of the same type, and he believed that instead of there being one fore and aft bulkhead, there might be two, as in Fig. 1. That would tend in a great measure to make her unsinkable, and leave the machinery, and a cabin fore and aft, to be used for passengers, out of danger. For ferry or river purposes, or for the channel service, he thought this structure much safer than a paddle-boat, even if the latter had overhanging sponsons, for there must necessarily be a gap on each side for the paddle wheels. He could hardly claim to be the first to place two pulling screws at the bow, but he believed that the bow screws working in unison with after screws was a novelty. Since the "Oxton" came from the Clyde, Mr. John Horn, late of Waterford, informed him that, about the year 1842, he applied two bow screws to a steam-tug canal boat of dimensions suitable to the locks on the Union Canal, Scotland. The boat was driven by a high-pressure engine having the screw shafts geared into an internal and external wheel. He was prevailed upon to change the position of the screws from the bow to the stern, but upon this being done the tug did not answer so well. The Union Canal soon after was purchased by the Edinburgh and Glasgow railway company, upon which Mr. Horn changed his employment, and heard no more of this screw steamer. From this Mr. Taylor gathered that bow screws, with the faces of the blades to the water, would do more duty in pulling and towing through water than screws propelling at the stern. But the screws of the "Oxton" were differently situated, they being back to back, and when the engines were reversed, the forward screws, which formerly had the round backs of the blades, and were working in conjunction with the after propellers, became powerful brakes and suddenly checked the forward progress of the vessel in consequence of the blades having their faces towards the water. In this respect, therefore, the "Oxton,"

if fitted with a saloon and upper deck, might be termed a passenger river locomotive. Mr. Taylor. He found from a report of the officials at the ferry made to the new committee, that, "when under way her motion through the water is steady, no horses having been thrown down, even during the gale which visited the river on the 13th of November, 1879. Neither is she affected by ordinary weather as soon as the passenger paddle boats are." And he might add, as an additional advantage with the four screws, that they need not be heavy or of large diameter, and the shafts being only 3 feet 7 inches below the water line could almost be reached for renewal, if need be, without docking the vessel. Also, in considering the passenger requirements, the bow screws if lost or damaged were not a very serious drawback as compared with safety of human life.

Mr. J. P. Symes said there was no doubt a great advantage in Mr. Symes. applying bulkheads to large steamers, but in the case of the small boats running above London bridge, it would be very difficult to arrange them, to give any accommodation whatever; and at present their accommodation below deck was of a very inferior character, and the ventilation and light extremely defective. He agreed with the Author that in rivers like the Thames and the Mersey, where there was much traffic, the greatest safety would be obtained by having full control over the steering and engine power. He exhibited models of two small steamers corresponding in dimensions to the above-bridge and the below-bridge boats on the Thames. They were light-draught boats, intended for passenger traffic. The dimensions of the smaller boat were: length, 80 feet; beam, 11 feet; depth, $5\frac{1}{2}$ feet. She was a paddle-wheel boat, drawing 1 foot 8 inches, was constructed for running on the coast of Spain over shallow sands, and had compound surface-condensing paddle-wheel engines. The effective diameter of the paddle-wheels was $7\frac{1}{4}$ feet, and the speed was ·11 miles an hour. She was rather smaller than the above-bridge London boats, whose dimensions were: length, 90 feet; beam, $13\frac{1}{2}$ feet; depth, $6\frac{1}{2}$ feet, and was not constructed with more than ordinary regard to safety. The ship was divided by four athwartship bulkheads into five water-tight compartments, the centre compartment containing the machinery. The boat had lofty cabins, the windows and lights being above the deck, and above the cabins were promenade decks. It was fitted with awnings fore and aft on account of the hot climate of Spain. The safety of the boat depended upon the control of the engine and steering power. With regard to strength, the vessel had

ymes. been loaded down with coals to about 3 feet draught of water, and crossed the Bay of Biscay, and a boat that would do that was strong enough for ordinary passenger traffic in smooth water. The other boat was of a much lighter construction, corresponding somewhat in dimensions to the boats running below London bridge. Her length was 140 feet, beam 18 feet, depth $6\frac{1}{2}$ feet, speed 12 miles an hour. She had been built for the African trade, and contained cabins on deck for only a few passengers. She was required for cargo and mixed traffic on the River Quanza, on the West Coast of Africa. She was built to carry machinery, coal, and 20 tons of cargo on a draught of 2 feet. On the trial trip she attained a speed of a little over 12 miles an hour with 27 tons of cargo, and a draught of 23 inches. The vessel was remarkably light so far as scantling was concerned, as there was not a plate in the hull exceeding $\frac{3}{16}$ inch thick. The vessels previously built had not answered the purpose, and in order to ensure success the contractors were ordered to build a ship at home, test it, and take the risk of running it out. The desired result had been attained, and the vessel could now run 30 miles higher up the river in the dry season, which was a matter of great importance. Formerly the cargoes had been brought by natives in their canoes. The boat had now run for two years, and had given great satisfaction.

Perkins. Mr. Loftus Perkins stated that he had long travelled up and down the river in a steamer of his own, and he had brought a cylinder for the inspection of the members, that they might see how it had worn. It was a high-pressure cylinder, working at 500 lbs. per square inch. He could not agree with the statement that the Thames steamers were managed badly. He had been in America and elsewhere, and he considered that the steering and the general management of the London boats were as good as any that he had ever seen. The steersman performed a double duty—steering and carrying a fender to defend the stern. He had never known an accident happen to the river boats. Naturally their consumption of fuel was very large, but they often stopped, and during a great part of the day they did not run. With regard to Mr. Taylor's statement as to the consumption of fuel in the case of the steamer he had described, he thought there must be some mistake, as it amounted to less than 1 lb. per HP.

Taylor. Mr. Taylor said the boat was not incessantly working under steam, but while stopping to load and unload was making steam.

Rogerson. Mr. John Rogerson observed that, in the earlier part of the

present century, open wherries propelled by rowers were employed Mr. Roger
for the conveyance of passengers by water between Newcastle and the towns of North and South Shields, at the mouth of the Tyne. These boats could only go with the tide, and make one trip each way during the day. The times of starting were always varying, and the boats occupied several hours on the journey of about 10 miles, not unfrequently grounding on the numerous shoals which then existed in the river. These were succeeded by a sort of floating omnibus, a rude imitation of the "Venetian gondola," called comfortables, having a raised covered cabin at the after part of the vessel; and they in turn were superseded, in the year 1814, by the "Perseverance," a small wooden paddle steamer. At various times attempts were made to organise a regular traffic; but as the boats were owned by proprietors acting independently, and were used indiscriminately for towing purposes as well as for passengers, the service was intermittent, tedious, and irritating to those who had occasion to have recourse to it. At that time there were only the two terminal landings, passengers for intermediate points being obliged to embark or disembark by small boats. Uncertainty and delay were the prevailing characteristics of the traffic, which altogether failed to keep pace with the industrial progress of the district. Recognising these inconveniences, and believing that a large traffic could be developed on the river, Mr. Rogerson gave his attention to the building of suitable steamers and to the establishment of a regular passenger line. The traffic on the Tyne might be divided under several heads. Above the bridges connecting Newcastle and Gateshead there was little movement of vessels, and only sculler boats and keels, sometimes towed by steamers, presented difficulties to be guarded against. Below the bridges ships came in large numbers to discharge at the quays of Newcastle and Gateshead. Tiers of vessels were moored to buoys at various places. There were frequent sculler-boat ferries. There was a constant movement of large sea-going steamers, and of tug steamers towing vessels or keels, or seeking employment; in a word, a ceaseless traffic coming up, going down, and crossing the river. This continued until within 2 miles from the mouth of the river. There were large docks on each side of the river. At high tide the water-way was crowded with vessels under tow; besides which there were tiers of vessels between North and South Shields. The breadth of the river varied from 100 to 300 yards; but in consequence of these tiers the river way was so narrowed that when meeting vessels under tow the passenger steamers had sometimes to make their way

Mr. Rogerson. inside the tiers. Then in summer the sands and neighbourhood of Tynemouth were a great resort to pleasure seekers. The steamers, therefore, had to be constructed so as to be able to run, at the proper season, to Tynemouth Haven. This portion of the traffic required that the steamers should have to some extent sea-going qualities; since, notwithstanding the large piers north and south of the harbour, broken water was frequently experienced. Wrecks had occurred during storms inside the piers, and on one occasion the passenger-steamer pier at Tynemouth Haven was cut in two by a wrecked vessel. Besides those characteristics of the traffic, some of the steamers made pleasure trips out to sea in summer.

He at first judged that fine lines would be best suited for speed, and that good accommodation and higher speed would attract an increase of passengers. He therefore built, in 1859, the "Louise Crawshay," of the following dimensions:—111 feet long, 6½ feet deep, and 14 feet beam. This vessel carried three hundred and fifty passengers, and had a pair of common condensing diagonal engines, of 30 nominal HP., cylinders 22 inches in diameter, and a stroke of 2 feet 4 inches, the draught of water being 4 feet. The boat plied regularly between Newcastle and North Shields. He next built the "Harry Clasper," to carry five hundred and eighty-five passengers—a still more commodious steamer, 115½ feet long, 16½ feet beam, 7½ feet deep, having a pair of engines of 40 nominal HP., cylinders 24 inches in diameter, a stroke of 2½ feet, and 7½ feet depth of hold; the draught of water was 3½ feet. The public responded to the facilities and accommodation, especially in visiting Tynemouth; and, having studied the saloon steamers on the Mississippi and Hudson rivers, on returning from America in 1860 he built the "Charlotte Annie Williamson," a saloon steamer, 114½ feet long, 16½ feet beam, 7 feet deep, and of 50 tons net and 82 tons gross register. The sponsons were carried out to the paddle-boxes, and extended fore and aft, the beams overhanging outside of the hull being supported by stays. The vessel accommodated three hundred and eighty passengers, and had a saloon deck 90 feet long, under which were fore and aft cabins; the engine-house was amidships, and there was a passage-way outside the saloons on the main deck. The engines were a pair of common condensing diagonal ones; the cylinders were 24 inches in diameter; the length of stroke 2 feet 6 inches; the HP. 40 nominal; the boiler, vertical tubular, was subjected to a pressure of 27 lbs. per square inch. Of two other vessels built at this time, the "Garibaldi," which had the saloon arrangements similar to the last, carried

two hundred and seventy passengers, and was 89½ feet long, 16 feet beam, 6¼ feet deep, and of 36 tons net and 55 tons gross register; the engines were common condensing oscillating, of 20 nominal HP.; the cylinders 18 inches in diameter; the length of stroke 26 inches, and the boiler a vertical tubular one. The "Wansbeck" was a double-stemmed boat, with a rudder at both ends; the shell plating was continued out to the sponsons; the saloons were partially sunk below the main deck. This vessel, which was built in 1861, and carried two hundred and eighty passengers, had recently been almost rebuilt, and was now the only saloon passenger steamer on the Tyne. The "Wansbeck" was 97½ feet long, 16¼ feet beam, 5½ feet deep, of 38 tons net, and 56 tons gross register, and was steered from a wheel-house amidships on the saloon deck. The engines were oscillating, of 30 nominal HP.; the cylinder was 22 inches in diameter, and the length of stroke 30 inches. Mr. Rogerson

In the meantime he erected landing stages at short distances apart on both sides of the river; but it was found that the class of steamer above mentioned, although adapted for the direct passage between Newcastle and North Shields or Tynemouth, was unwieldy for general purposes, not being easily handled. He might mention that, as the North and South Shields Ferry Company had a monopoly for conveying passengers between North and South Shields, he applied, in conjunction with some friends, for an Act of Parliament; and the passenger line started by him was incorporated as the Tyne General Ferry Company in 1862.

Subsequently a somewhat different type of steamer was adopted, and in 1865 the "John Edwin" was built. This vessel was 100 feet long, 13 feet 10 inches beam, 6½ feet deep, 99 tons builders' measurement, 36 tons register, and had a draught of 3¾ feet, representing a displacement of 61 tons. The vessel was certified for two hundred and seventy-five passengers; the speed was 10 miles per hour; the engines were a pair of common condensing oscillating, the cylinders 20 inches in diameter, and the length of stroke 2 feet, indicating 122 HP.; the boiler was longitudinal, multitubular, fitted with a copper back tube plate and brass tubes; the pressure was 30 lbs. on the square inch; the paddle-wheels were 10 feet in diameter with feathering floats. Three transverse bulkheads divided the hull into four watertight compartments, strong sponsons protected the engine-room from external injury, and a wooden fender 9 inches broad was carried round the hull immediately below the deck line for the protection of the ends of the vessel. The cabins were below the

Mr. Rogerson. deck, and were lighted and ventilated by skylights. The boat was steered from a bridge forward of the funnel by the captain, who was protected from the weather by a wheel-house, the upper part of which was fitted with carriage windows on all sides. The engines were worked from the deck, and had link motion reversing gear. The engineman was immediately behind the captain, from whom he received orders direct.

The passenger service of the Tyne was now carried on by four direct ferries, viz., the North and South Shields Direct Ferry, the North and South Shields Market Place Ferry, the Whitehill Point Ferry, and the Howdon and Jarrow Ferry; three of these carried passengers only, the fourth conveyed besides, carts and general street traffic. A line of steamers also plied eastward from Newcastle to Tynemouth, a distance of 10 miles, and westward to Elswick, a distance of 2 miles. The number of passengers was six millions per annum. This great traffic was conducted over a crowded waterway, the river being navigable by large vessels at all times of tide. The clearances outwards of four of the principal ports of Great Britain in 1876 were: the Tyne, 16,581 vessels; the Thames, 15,883; Liverpool, 13,496, and Glasgow, 5,453 vessels; the Tyne standing highest in the number of vessels.

It would thus be seen that the conditions under which the Tyne passenger traffic was carried on, were such as to require a class of steamers easily and quickly handled. In the run of 12 miles there were now no less than twenty-three stations, many of them difficult of access on account of the tiers of vessels on either side which had to be approached at nearly right angles with the line of the river. Unlike the Thames and the Clyde, the Tyne passenger traffic was conducted during many hours of darkness, thus materially increasing the risk of collisions. The principal direct ferry ran night and day, and the up- and down-river steamers began plying at 5 A.M., in winter as well as in summer, for the accommodation of workmen proceeding to their employment, and continued running every half hour from each end till 7 P.M. in winter, and 9 P.M. in summer.

The Tyne traffic was totally different from that on the Clyde, therefore no comparison could be made between the classes of steamers employed. The only resemblance to the service on the Mersey occurred in the case of the principal ferry-boat plying between North and South Shields, which resembled the Birkenhead ferry-boat on a small scale. The "Tyne," one of the direct ferry-boats referred to, carrying six hundred and eleven passengers, was a single-stemmed flush-decked boat 99½ feet long, 26½ feet

beam, 43 feet broad over the sponsons, and $8\frac{1}{4}$ feet deep from keel to gunwale. The hull was protected by a strong sponson projecting the width of the paddle-boxes, and carried fore and aft. The boat was steered from a wheel-house amidships, immediately over the engine-room, elevated on a large hurricane deck which served the double purpose of a promenade and a shelter in wet weather. The propelling power was by a pair of disconnecting side-lever engines of 80 nominal HP., with two cylinders 26 inches in diameter, and of 3 feet 9 inches stroke, and two flue boilers with a working pressure of 20 lbs. per square inch. The vessel drew 4 feet 9 inches of water, and had transverse watertight bulkheads; but not the longitudinal ones described by Mr. Carson as an important factor of safety in the Mersey boat. The principal cabins were below the main deck. Mr. Roge

The Thames service from London bridge to Chelsea, and down the river to Woolwich, represented more nearly than any other that of the Tyne. Suppose the Thames to possess the best design of steamers obtainable, a similar class of vessel might be expected on the Tyne; but the Tyne boats, though of similar dimensions to the above-bridge boats on the Thames, differed from the latter in several important respects, the excessive displacement, and greater draught of water being specially noticeable. The reason was that during four or five months of the year the boats ran to Tynemouth to a point outside the bar, though within the limits of the piers; also, when specially surveyed for the purpose, they were employed on trips along the coast, being thus subjected to strains from rough water; they were heavier than the Thames boats, and drew more water. The draught might be lessened by making the boats longer, but the length could not be materially increased on account of the difficulty in approaching some of the landing stages. This class of steamer had conformed most nearly to the peculiar conditions of the service.

With a view to obtaining economy in the consumption of fuel, at the instance of the Chairman of the Company, the "Perkins" patent engine and boiler had been fitted in one of the boats. The safety-valves were loaded to 450 lbs. per square inch, and the boiler tested to 2,000 lbs. on the square inch. The engines had three cylinders, one high pressure 10 inches, one medium 14 inches, and one low pressure 28 inches, in diameter. The length of stroke was 18 inches, and the indicated HP. 150. The fuel was gas-coke, and the consumption under trial on a day's work of twelve hours was 25 cwt., or $1\frac{1}{2}$ lb. per indicated HP. per hour. The vessel had run with passengers ninety-one days, making in all 5,582 miles, in

Mr. Rogerson. addition to a great number of trial trips. After this period, during six months of which a Board-of-Trade certificate for passengers had been held, the boiler tubes were drilled for the surveyors, and proved perfectly clear and free from scale. The consumption of second-class steam coals in other boats doing the same work as the "Loftus Perkins" was 45 cwt. per day, costing 13*s.* 3*d.*, as against 7*s.* for the "Perkins," being a saving in favour of the latter of 37½ per cent. in the consumption and 47 per cent. in the cost of fuel.

Another general question was whether, by reason of its intrinsic merits and moderate cost of production, mild steel was not likely to supersede the use of iron for engineering and shipbuilding purposes.

He had a steel boiler at the Stanners Closes Steel Works, near Wolsingham, which had been working continuously for more than ten years; it had cost little for repairs, and every plate in it remained nearly as sound as when first put in. It was of the usual Cornish type, 6 feet 6 inches in diameter, by 33 feet long, fitted with two furnaces each 2 feet 9 inches in diameter, and 33 feet long; the plates were of Attwood's steel, ¼ inch thick throughout, except the end plates, which were ½ inch thick; the whole was double riveted with steel rivets, and all the holes had been drilled. This boiler, which was loaded to a steam pressure of 50 lbs. per square inch, supplied steam to two steam hammers, one a 2-ton and one a 10-cwt. hammer; it likewise supplied motive power to a machine for washing blacklead. The consumption of fuel for twelve hours was 33 cwt. This boiler had been built by Mr. Daniel Adamson, of Manchester, who informed him that he had constructed fourteen hundred steel boilers, all now in use and working at a pressure of from 60 to 160 lbs. per square inch.

A boiler made of Attwood's steel had been fitted to the "Wansbeck" in April last. The boiler in this boat was of the cylindrical form, with eighty-six horizontal tubes, 3½ inches in diameter by 6 feet long; it was 9 feet in diameter by 8 feet 3 inches long, and was fitted with two furnaces, each 2 feet 9 inches in diameter and 6 feet long; the plates, as well as the tubes, stays, &c., were made of Attwood's steel, $\frac{5}{16}$ inch thick; the tube plates were ⅝ inch thick, the shell and furnaces were double riveted with steel rivets, and all the holes were drilled. The boiler was loaded to a pressure of 30 lbs. per square inch, and supplied steam to two 22-inch cylinders, the length of stroke being 2 feet 6 inches. The consumption of coal was 67 cwt. per twelve hours.

In September 1877 he witnessed a series of experiments by Mr.

D. Adamson, at Dukinfield, with the object of testing the endurance of iron and steel when subjected to violent percussive forces, such as were produced by the explosion of gun-cotton or gunpowder; twenty-seven pieces of plates were tried, each piece of a different quality, and selected from the principal manufacturing districts. The iron was the finest boiler-plate, and the steel had been manufactured both by the Bessemer and Siemens-Martin processes. Each piece of metal was placed on a cast-iron anvil block, having a segment of a sphere hollowed out on the top; about 8 inches above the plate was fixed the gun-cotton which was exploded. The result of these experiments afforded conclusive evidence in favour of mild steel so far as regarded its power of resistance to a sudden and violent shock[1]. Mr. Rogerson.

In order to have some idea of the comparative corrosion of iron and steel, experiments were made at the laboratory of the Weardale Iron and Coal Company, Limited, at Tudhoe Iron Works, on specimens of iron and steel plates of the following chemical composition:—

—	Mild Steel.	Medium Hard Steel.	Tudhoe Best Best Iron.	Tudhoe Crown Iron.	Common Iron.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Iron	99·354	98·400	99·000	98·900	98·800
Carbon	·115	·330	Trace	Trace	Trace
Manganese . . .	·504	1·008	·216	Trace	Trace
Silicon	·055	·065	·111	·107	·177
Sulphur . . .	·028	·022	Trace	Trace	·008
Phosphorus . .	·037	·075	·165	·217	·532
Copper	Trace	Trace	Nil	Nil	Nil

These specimens were originally 2 inches square by $\frac{3}{8}$ inch thick, and had been immersed in a bath of water containing 1 per cent. of sulphuric acid, and the loss in weight recorded every twenty-four hours. The "mild steel" in seventeen days only lost 4·8 per cent. of its weight, while the iron samples in the same time lost from 34·7 to 79 per cent.

Guided by these and other results, there was now in course of construction for the Tyne Ferry traffic, a steamer of Weardale steel, which would be 6 feet longer, 14 inches wider, and 4 inches deeper than the "Tyne" previously described. It would give the

[1] *Vide* "The Journal of the Iron and Steel Institute," 1878, p. 383.

Mr. Rogerson. same displacement, but would carry fifty additional passengers on 9 inches less draught of water. The plates were $\frac{3}{16}$ and $\frac{1}{4}$ inch in thickness; the total weight of steel being 30 tons. The steel was tested according to Lloyd's rules, and every plate, angle, &c., had an ultimate tensile strain of between 27 and 31 tons per square inch of section, and an elongation of not less than 20 per cent. in a length of 8 inches. The chemical composition of the steel was:—Iron, 99·375; carbon, ·110; manganese, ·400; silicon, ·028; sulphur, ·037; phosphorus, ·050; and copper, trace; total, 100·000. The boiler would also be built of Weardale steel of the same chemical composition as that used for the boat, and in accordance with the Board of Trade requirements, which, in the case of boilers were "that a strip cut from every plate shall stand an ultimate tensile strain of between 26 to 28 tons per square inch of section, and shall show an elongation of not less than 20 per cent. in a length of 10 inches."

The advantages to be obtained by the use of steel for marine purposes would be decrease in weight, increase of strength, greater ductility, and probably extra durability. Such, briefly, were the results of experiments that had come under his supervision and direction in regard to steel up to the present moment; such the action already taken in regard to it—that was in a boiler already in use, and a passenger steamer now building—and such the expectations which he anticipated would be realised at an early period.

Mr. Bramwell. Mr. F. J. BRAMWELL said the Paper had been avowedly written in consequence of the accident to the "Princess Alice." No doubt that accident had excited the attention of the public to a very large extent, and also, happily, it had excited the attention of gentlemen such as the Author of the Paper and that of others competent to advise what should be done for the future. The Author had stated that he had considered the various circumstances which should be taken into account in dealing with such a subject, and Mr. Bramwell was glad he had intended to bear in mind that it was not desirable to propose such remedies as were prohibitory in consequence of their adding too much to the cost of the work. Nevertheless, he did not think that the Author had sufficiently taken those matters into consideration in regard to the up-river Thames steamers. He gathered from the Paper that the Author considered that in order to have safety there must be a cellular system of construction. In the case of an up-river steamer 16 feet beam, it was proposed to have a continuous longitudinal bulkhead. That certainly seemed to him (Mr. Bram-

well) very much out of keeping with anything like use or comfort of Mr. Bram the lower part of a steamer of that size. It might be said, "Look at the steamers upon the Mersey and upon the Clyde, and it will be found that the passengers are disposed of in saloons on deck." But bearing in mind the nature of the navigation of the upper Thames, it would be seen that the steamers were limited in their beam by the width of the bridges, so that it was impossible to have those wide sponsons which were put forward as a means of increasing the deck room and of protecting the sides from the effect of a blow; they were also limited in height by the bridges, so limited that, even with lowering funnels and paddle-boxes kept low, it was not uncommon (as he himself had experienced at Hammersmith Bridge) for the boats to be detained a considerable time, unable to get through until the tide fell. Thus these steamers were precluded from width, from height, and, owing to shoals, from draught of water: they therefore must neither be wide, nor lofty, nor heavy. Under those circumstances it seemed to him that there was not much room for improvement in the manner suggested by the Author by the cellular construction, or by a longitudinal bulkhead dividing a 16-feet-beam boat into two equal parts. With regard to the navigation below bridge, Mr. Mackie, who had paid so much attention to the subject, and who, in common with all those who desired to save life, deserved their warmest approval, said that a boat might be made of two continuous longitudinal bulkheads from end to end; then there would be the external skin and the two bulkheads, and by suitable transverse divisions there would be an almost unsinkable structure, without adding much to the weight. Was he right in that supposition? He had complained of the plates of the "Princess Alice" as being of little more value than brown paper (a phrase that had been much used), those plates being only $\frac{5}{16}$ inch. What did he propose to do? Was he going to make the external skin of the boat thinner? He supposed not. If he intended to have the internal bulkheads from end to end, what were they to be? Were they to be $\frac{5}{16}$ inch, or something thinner? If they were to be something thinner, they might answer so long as the outer skin was uninjured and they were in the dry, but directly the outer skin was injured, if the bulkheads were not strong enough to stand against the pressure of water—when they became as they would then become the external parts of the vessel, they would give way, and the vessel would sink. It appeared to him, therefore, that it was not possible to retain the same weight of vessel and to adopt the plan proposed by Mr. Mackie. With respect to

Bramwell. the "Princess Alice," he did not think there was any proper complaint to be made against the thinness of the plates of the vessel, or that there was anything in the suggestion that the vessel would have been practically safer if the plates had been thicker. He said so for this reason: when two vessels came into collision, if they were of equal strength and struck each other equally, perhaps both would go down; but if one were strengthened, it might stop up and the other go down. If a brass vessel and an earthenware pot were going down stream, it would be a bad case for the earthenware pot. But you could not so strengthen vessels that both would stand; one of them would go down if they came into collision. If a proof of that were wanted he might refer to the lamentable accidents that had taken place in the English and in the German navy, where vessels built with plates of enormous thickness and with numerous watertight compartments had come into collision and had gone down. If the question of expense were wholly unimportant, still it was idle to suppose that you could so strengthen a river passenger steamer that, when she came into collision with even an ordinary merchant vessel with a heavy scantling, she would not go down. He knew that the view he was taking was not a popular one. He remembered the applause that was given to those who had proposed to save life at any cost, and he was aware that he was laying himself open to the charge of being indifferent to life. That, however, would not be a deserved charge; true he was of opinion that it was possible to buy life too dear, and in considering the cost of the purchase the number of lives to be saved must be taken into account. Now what had been the result of the navigation on the Thames? He was old enough to remember it for fifty years. The percentage of loss of life by accident had been extremely small, and if to lessen that very small percentage plans were proposed which would result in costliness of structure and working, the result would be practically to prohibit cheap fares and cheap trips down the river, and thus in the end more harm than good would be done. He knew that when any one came forward in all earnestness and sincerity and said that life had been lost, and proposed that certain things should be done with a view to avoid that calamity, it was a taking thing, and everybody was inclined to agree with him. The Board of Trade—that most mischievous institution in respect to its excessive interference with marine engineering—was called upon to give its help, and the result was harm and not good. If the Board of Trade managed the pressure upon the railways, he believed there was not a single railway

that would not have to lower the pressure on its locomotives Mr. Bram
from 140 lbs. to 80 lbs. the square inch in order to pass muster. Complaints had been made that the Thames ships were without signalling apparatus, and that the barbarous custom of calling was resorted to. That, however, was only half a fact. The signalling was not done by calling, but by hand signalling—the captain moved his hands to the call-boy. He would ask whether any of the travelling members of the Institution knew of any place in the whole world where vessels were navigated with the ease and ability exhibited on the Thames? The vessels went along with a three-mile tide in their favour, and yet they were brought up alongside the pier in a manner quite different from that adopted abroad, where it was the custom to turn the boat round and go in with her head against the stream. With one hand the captain directed the steersman, and with the other communicated with the call-boy. The plan might be inartistic, but it worked well; and he knew no place where, although the appliances might be much better, the practice was so good.

Mr. J. I. Thornycroft desired to offer a few remarks on Mr. Thorn
the Paper, but he would make them with much deference, as croft.
many naval architects were far better able to deal with the subject, having devoted their time to the construction of the very vessels under consideration. Mr. Bramwell had shown that to strengthen the vessels in the way proposed might be very expensive, and the Paper contained some evidence to show what that expense would be, for the number of passengers was generally given, also the displacement and the speed of the vessels. Taking Mr. Samuda's boat, the weight of the passengers was about 48 per cent. of the displacement. That was large in proportion to the others. The speed was not high—10 or 12 miles an hour. On the Mersey the attempt to make the boats proof against collision had been successful. He did not say that they were safe from a violent collision with a large ship, but he thought there was a great chance under ordinary circumstances of their swimming in the event of collision, although they would no doubt be injured. It had been proposed to put longitudinal bulkheads in narrow boats built for speed, but it did not appear to have occurred to those who made the proposition that the effect on the stability of the vessel might be so destructive as really to make the proposed remedy a disadvantage. In the Mersey boats the weight of the passengers carried was only 17 per cent. as against 48 per cent. in the London boats. In order to divide a boat into watertight compartments, a very great amount of material had to be expended, and a larger expendi-

horny- ture of power was required to get the same speed. It was curious that in the boats supposed to be stronger, and that could go further down the river Mersey, the percentage of the weight of the passengers was 21 instead of 17. Why the stronger boat should be the lighter he could not understand. On the Clyde there were beautiful examples of vessels built for high speed. The speed attained was said to be 22 miles per hour, and the percentage of the weight of passengers was 21. If it was required to build a boat divided into compartments with the same expenditure of material per passenger, the speed would only be 10 knots instead of 22 miles; and if the boats of the Thames were so hampered as to have their speed reduced to 10 knots, he thought that for long trips they would be practically useless. With regard to the effect of high-speed engines, there was a model on the table of one of the Mersey ferry boats—a screw boat—and the gentleman who had exhibited it had stated that the vessel was considerably lighter for the number of passengers carried. She had four screws and two shafts running the whole length of the vessel. That appeared to him one shaft more than was necessary. He thought that if one screw was retained on one side at one end, and the other screw at the other side at the other end, both screws retained being of a slightly larger diameter, the friction of the shaft would be reduced, and the efficiency of the boat probably be increased, the steering qualities remaining nearly the same. What an engine could do really depended on how many reciprocations it could make in a unit of time. A paddle vessel with very large paddle wheels could only make a very few. As to the wear and tear, it might be somewhat excessive or greater in rapid-working engines, but he thought the saving in first cost would more than balance the wear and tear. He thought that the screw might be adapted in a modified form to shallow draught, and to a great extent take the place of paddle wheels as now used. He hoped it might be found possible to work out the system so as to give satisfactory results. His firm had built a vessel having a very limited draught, 30 inches, and she was able to tow on the Nile very successfully. She might have been much larger had she not been required to be used as a towing vessel. He thought there were means at hand by which the draught of water of vessels of similar power could be much further reduced, and a vessel having equal power could be built at about 18 inches draught.

ramwell. Mr. Bramwell asked what would be the maximum thickness of the plates in a vessel of that draught.

horny- Mr. Thornycroft replied that the thickness would be about $\frac{1}{8}$ inch.

Mr. J. R. Ravenhill said it was stated in the Paper that under Mr. Rave
the conditions of the navigation of the Thames above bridge, "great strength of hull would defeat its object. Great handiness is necessary, and when a choice must be made between strength to resist the force of collisions and handiness to avoid them, in the latter quality lies the greater probability of safety." It might be taken that the Author, in speaking of the greater probability of safety, alluded to handiness only; but in his opening remarks he certainly spoke of the strength of the hull, and if he had stated that the same remark would apply to the Thames between London bridge and Gravesend, the Paper would have been very much to the point. Mr. Bramwell had, in his usual lucid way, referred to the above-bridge navigation. He could not remember so long back as Mr. Bramwell; but he had stood many times on the piers above bridge, and on the boats themselves, sometimes in company with foreigners, who had invariably admired the way in which those boats had been handled. The best proof of the efficiency of the boats was the fact that, dating back, as the service did, more than forty years, there had been no serious accident or collision. He wished that Mr. Bramwell had said something about the below-bridge traffic; but he had a few figures on that subject which might prove interesting. At certain times of the tide the river eastward of London bridge could only be compared to one great tidal dock. If there were sluice gates across the bridge, and some ordinary dock gates down the river, the tidal dock would be complete. The traffic had grown to an enormous extent; that on the Tyne, to which reference had been made, was nothing in comparison with it. The number of sea-going vessels arriving in London—sail and steam, foreign and coasting, amounted, in 1874, to 43,848, with a gross tonnage of 8,337,977 tons. In 1878 the number of vessels had increased to 47,728, with a gross tonnage of 9,415,873 tons. In addition to that enormous tonnage, which the waterway of the Thames had to provide for, there were all the river craft, the river steamers and barges plying within the port, which were not included in the Custom House returns. The barges alone amounted to about 1,000 a day, passing from the docks below bridge into the Thames; and the total number of barges at that time registered amounted to 7,000. Taking those vast figures into consideration, had the accidents been numerous or serious? In the years ending the 30th of June 1875–76–77, 131 vessels, including 95 barges, had been sunk by collision between London bridge and Yantlett creek. Of those, many succeeded in reaching the shore before sinking, and nearly all were raised. The number of lives

venhill. lost was 15. Above Gravesend, between June 1877 and June 1878, 419 casualties were reported to the Board of Trade, of which 373 were collisions, and in which 836 vessels were concerned. The total number of lives lost was 6. Thus the number of lives lost amounted to 21, and he believed they were all connected with the crews, there being no passengers in the usual acceptation of the word. He did not wish to make any allusion to the unfortunate accident with regard to which he had had the honour to serve on the Committee of Inquiry; but he should like to draw attention to one important point in connection with it. The navigation of the Thames was carried on under totally different circumstances from those existing in the Clyde, the Mersey, the Tyne, or any other river in the world. There was an old guild dating from the 14th or the 15th century, called the Watermen's Company, who possessed the greatest possible powers that could be held by any body of men in connection with the navigation of the Thames. He was a Conservative, and had no wish to see an old company, that doubtless had done much good, swept away; but he maintained that the company should move with the times. It was something past comprehension that a vessel carrying between 800 and 900 human beings was compelled to be navigated by a man earning 50*s.* a week, and that the owners of the vessel were debarred from going into the open market and buying the best skill and seamanship that the world could supply. The Paper, according to the reading of many, implied: Mersey, perfection; Clyde, good; Thames, very bad. Mr. Ravenhill had the authority of the senior member of one of the firms alluded to as having built a vessel for the Thames, to say that everything was brought to him—that he was asked to build a vessel for old machinery—that he had simply carried out the plans furnished to him, and had nothing to do with the design. He believed the second vessel alluded to was also given to the builders under similar circumstances, but he could not say so with the same authority. With regard to the Gravesend boats, he remembered the time when they were the pride, not only of the Thames, but of Europe. When he was an apprentice it had fallen to his lot, on more than one occasion, to have to take a vessel, well known on the Gravesend station, and measure her against a new comer in a good slogging race all the way from Gravesend to Blackwall. That was in early days, before Mr. Bramwell was troubled with his nightmare of the Board of Trade. Engineers and shipbuilders could then do as they liked, and they did as they liked. The Thames held its own, and he believed there were firms on the Thames now, who, if things were left entirely to them, could hold their own as

in days gone by. No vessel could be built to stand a huge Mr. Raven screw collier coming right into her amidships; but the difficulty that owners or companies had to deal with was that railways had run off the vessels he had alluded to, and there was now no such thing as Gravesend passenger traffic by water. There was during the summer a Gravesend excursion traffic, but the owners had been so hard put to it to earn a dividend that they had been compelled to introduce a refreshment bar on board the vessels. If they were required to have bulkheads for the vessels in the way suggested, they might as well be told that the traffic should cease altogether. An excursionist would only give a few pence for his ticket, and the receipts therefore were very small in comparison with the large sums earned by the Birkenhead Ferry. So long as the traffic existed between London bridge and Gravesend, the passenger steamer must be a compromise. There had lately appeared on the Thames a class of vessel for which the public had mainly to thank Mr. Thornycroft. Some few years had passed since he had astonished them by the results of his screw launches. When Mr. Bramwell read a Paper "On Quick Steam Launches,"[1] at the Institution of Naval Architects, many of them shook their heads and said they "should like to see it done." Out of the launches had grown the torpedo vessels of the present day. There were now two firms in London producing torpedo boats that had attained a speed hitherto unknown in the history of steam navigation. From the result of those vessels he believed much might be gained with reference to light draught passenger ships of the future. They had led the way to higher pressures. The plan which had proved successful on board those vessels was about to be tried on a large scale by the Admiralty for the engines of a vessel, building at Chatham, called the "Polyphemus;" and, should it be a success, he believed in a short time there would be a vast difference in machinery connected with river navigation. Experiments were also being made with a much lighter form of boiler even than those working on board torpedo vessels. If that also succeeded (and he had seen a boiler at work that had run 1,500 or 1,600 miles, and appeared to be working efficiently) there could be no doubt that additional strength could be given to passenger steamers with good effect, and without increasing the cost of the hull and machinery. If an artificial blast were adopted, two bulkheads could be introduced, one forward and one aft, between the engines and the stokeholes, which would strengthen the ship and help her in the event of a

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[1] *Vide* Transactions Inst. Naval Architects, vol. xiii., p. 269.

avenhill. collision by reducing the present enormous engine space. The present great stoke-hole hatchways, where there were a number of half beams would also be got rid of. It was all very well to say that they were as strong as if the beams went right across, but he should prefer them to go across, and that might be done. In those respects passenger ships might be improved, and in such improvements, he believed, the Thames would lead the way in the future as it had done in the past.

eloe. Mr. CHARLES H. BELOE said there was no Waterman's Guild on the Mersey, and men could be obtained from the open market. The wages paid were: the master, 50*s.* a week, the mate, 35*s.*, and the crew, 30*s.*, and there was no difficulty in obtaining good men at those prices. With regard to the "fancy" fares mentioned by the last speaker, the fare was only a penny, and he did not think that could be well reduced. The largeness of the receipts was of course due to the enormous traffic between Liverpool and Birkenhead. By the courtesy of the Wallasey Local Board he was enabled to exhibit a model of the last passenger steamer built for the Mersey. The following were the conditions enforced by the Board in regard to the design. The number of water-tight compartments was not to be less than seven. The paddle shaft was to be in the centre of the vessels, so that they might have an equal rate of speed going either end first. The engines to be arranged so that the cylinders should be one on each side of the shaft. The engines, boilers, and paddle shaft to be under the deck. The draught of water not to exceed 5 feet with the usual amount of coal, and with 900 passengers on board. The guaranteed speed to be not less than 13 statute miles per hour in smooth water. The passenger boats to have a certificate for at least 900 passengers. The saloon not to be less than 80 feet long, 12 feet wide, and 7 feet high. The length of the vessels not to exceed 150 feet. That limit as to length was imposed by the Dock Board, who would not allow a steamer of greater length to occupy a berth at the Liverpool landing stage. Another condition was that the deck should not be more than 5 feet 6 inches above water amidships, in order to suit the level of the landing stage at New Brighton. To comply with those conditions it was necessary to employ two boilers to balance the weights, and having to keep them under the deck entailed the use of low-crowned boilers, with the risk of priming, which made it a matter of some difficulty to attain the desired speed. Fifteen or sixteen firms tendered, and the tender accepted was that of Messrs. T. B. Seath & Co., of Rutherglen, Glasgow, who had supplied two pas-

senger steamers from the designs of Mr. Alexander Richardson, Naval Architect, Liverpool. The dimensions were: length, 150 feet; beam moulded, 25 feet; depth, moulded, 10 feet 6 inches. Driven by a pair of diagonal oscillating surface-condensing engines made by Messrs. David Rowan & Co., of Glasgow, having cylinders 36 inches in diameter, with a stroke of 5 feet. Boiler pressure, 40 lbs. The saloon was 93 feet long, 13 feet wide and 7 feet high. The stipulated number of watertight compartments had been exceeded, the boats being divided into twelve, without any openings in them; and the coal bunkers could be closed by watertight doors, making sixteen watertight compartments in all. The largest compartment was the engine-room, but before this could be penetrated in a collision the heavy sponson or paddle-box would have to be cut through. He was sorry that Mr. Carson had not given more information on the subject of cargo boats. The "Oxton," with four screws, was intended entirely for cargo purposes, being the last cargo boat built for the Mersey and at work. Another boat had since been built for the Wallasey Local Board, from Mr. Alexander Richardson's designs, but it had not been set to work on account of the landing stage at Seacombe not being completed. The Seacombe boat had to comply with the following conditions: to carry a deck load of 100 tons; to load and discharge "end on;" to have rails on deck to receive railway wagons; draught of water not to exceed 5 feet when light; height of deck above water at bow and stern not to exceed 6 feet when light; speed not less than 9 miles an hour. The boat was divided into seven watertight compartments. As to the condition to load "end on," it was somewhat strange that the corporation of Birkenhead did not adopt that principle in the "Oxton," where there were side gangways, as shown in the model, two on each side. No doubt where the "end on" principle could be adopted for goods traffic it was much superior to the side loading, because vehicles could drive straight on to the steamer and straight out again at the other end without having to turn round, which was a difficult operation with a heavy load on a slippery deck. The Seacombe luggage boat was designed to load "end on," to accommodate her to the new stage at Seacombe, which was being built from Mr. Carson's designs. It was formed with a recess at one end. Provision had been made in the Liverpool stage for a similar embayment, but a double one, the stage being of course much larger. Owing to the great velocity of the tide in the Mersey it was impossible for vessels to lie "end on" to the stage at right angles to the river; hence the necessity of an

Mr. Beloe

r. Beloe. embayment deep enough to receive the whole length of the vessel. The embayment on the Liverpool side had never been used, and it was doubtful whether boats would be able to enter it, owing to the strength of the current. The Seacombe stage was left open at one end, and it remained to be seen how it would work. The other requirement, that rails should be laid on the deck, was somewhat peculiar, for although the Seacombe stage was connected with the railway system, the Liverpool stage had no such connection, so that if the wagons were brought across in the Seacombe boat they must stop there. Perhaps in no part of the world had the ferry-boat system been adopted so largely as in the United States, and there the "end on" system of loading had been carried out in every case where it was practicable. In the ferry-boats crossing the Hudson and East River at New York the landing places were provided with rows of piles driven into the river on each side forming a sort of blunt V. The boats were semicircular at each end, and as they entered in between the rows of piles they were guided up to the exact spot required; then platforms were lowered down to them from the shore, and vehicles could readily pass on board. The boats were of somewhat peculiar construction. They were driven exclusively by what was known as the walking beam-engine with a beam overhead, and a single cylinder was employed in most cases. The engine was very narrow, occupying but little space, but owing to the extreme light draught it could not be contained below the deck. There was room on each side of the engines for a row of vehicles; and on the sponsons, which projected like those in the Claughton, there was a narrow cabin built on each side, the passengers entering at one end and going out at the other. The whole boat was roofed over except a small space at each end. The captain steered from a pilot-house erected on the roof near the bow, changing his station to another pilot-house at the other end when proceeding in the opposite direction. No deck hands were employed, the attachments at the shore being made by men at the landing. The gates at the ends of the boats were generally made on the lazy-tongs principle, folding up very easily and occupying but very little space. He wished the Author had said more about the engines employed in working ferry steamers. A peculiarity of American engines was that nearly all were driven by double-beat valves, worked off a cam shaft instead of by the slide-valve used in most English marine engines. He thought that the double-beat valves possessed a great many advantages, especially for steamers that had to be stopped and reversed very quickly. Any one who had seen the men working

the large engines of the "Bristol" and "Providence" (two of the Mr. Beloe.
largest river steamers in America) would be struck by the ease with which they were handled. There was a single cylinder 110 inches in diameter and with 14 feet length of stroke, and it was easily worked by two men, when going in and out of the harbour. In the hull were the dining-rooms and bars and the boilers; on the main deck were ladies' cabins, offices, and cargo space and engine room; on the upper deck were two main saloons with state rooms all round them, and above that another range of state rooms opening on to a balcony running round the two saloons. Their height out of water was very great, and for a short portion of their journey they were exposed to the roll of the Atlantic. They had always done their work satisfactorily, and without incurring any danger. He was, however, once caught off Sandy Hook in an American river-boat that ventured there, and he was bound to say that her behaviour was the reverse of pleasant, and the passengers were all very glad when they got into smooth water. The boat was going on a pleasure excursion and was caught by the wind broadside on and nearly capsized. Of course it was never intended that the boat should go so far out to sea. He had recently read a description of an enormous ferry-boat just launched at San Francisco, called the "Solano," which had a greater width of beam than any other vessel afloat. Her measurements were as follows:—"Length, 424 feet; height of sides in centre, 18 feet 5 inches; height at ends, 15 feet 10 inches; width over guards, 116 feet. The 'Solano' will have two vertical beam engines of 60 inches diameter and 11 feet stroke, built by Harlan and Hollingsworth, Philadelphia. The wheels are 30 feet in diameter, with buckets having a face of 17 feet. Eight steel boilers, each 28 feet in length, will be provided, and will be made in pairs, with a smoke stack to each pair. Four Pratt trusses give a longitudinal stiffness, and connect the deck and bottom of the boat in true bridge style. She is a double-ender, and has four rudders at each end, worked by a hydraulic steering apparatus operated by an independent steam pump. By this improved method of steering, she can be handled by one man where ordinarily three would be required. The engines work independently, each moving one wheel, which will revolve independently of the other. The boilers are on the deck. Four tracks will be placed upon her decks, which will accommodate forty-eight freight cars or twenty-four passenger coaches. Her slips will be provided with aprons 100 feet in length, which will admit of cars being taken aboard without uncoupling from

Mr. Beloe. the engine." He ought to state that these details were taken from a San Francisco newspaper, and that he could not be responsible for their accuracy. He wished particularly to draw attention to the use of trusses in most of the American river steamers to strengthen the long shallow hulls. He could not help thinking that in such boats as those on the Clyde and the lower reaches of the Thames, such a method of construction would greatly strengthen the vessels without materially increasing their weight. He was one of those who thought that if the "Princess Alice" had been so strengthened she would not have broken in two as she did when the water found its way into the engine-room. A vessel built as she was, having a depth $\frac{1}{18}$ of her length, was not capable of bearing the weight of water in the central compartment. It was of no use to divide a vessel into compartments, if, when the compartment was penetrated and filled with water, the weight of the water broke the vessel in two. He believed if the trusses to which he referred were generally adopted the vessel would be safe enough to enable her to be beached before sinking, especially in narrow waters like those of the Thames. With regard to the remarks of Mr. Bramwell and others that it was impossible to divide vessels into water-tight compartments without increasing their weight to an enormous extent, he thought that the model exhibited was a complete answer to them, showing that the thing could be done. There was another element of safety in the "Claughton" which the Author had not described—the rubber or fender—running nearly her whole length just above the water line. It was applied to those vessels in consequence of one of them having been nearly sunk on the Mersey, by a barge or flat, which being very low in the water was not stopped by the overhanging sponsons, but went underneath and fractured the vessel's side. The accident created a great scare at the time, and each of the Birkenhead boats was put in dock and fitted with a rubber forthwith. He did not think the experiment of ramming had been tried since the rubber had been put on, but he had no doubt the result was beneficial. The boat—a model of which he had exhibited—was intended for working in the lower reaches of the Mersey down to the mouth of the river, where it would be exposed to much heavier seas than anything the "Claughton" had to encounter. From the distance she had to go, and the speed she had to attain, it would not be advisable to construct her upon the same plan as the "Claughton," with an overhanging deck carried to such an extent, but he believed, for the traffic for

ι it was intended, the "Claughton" was one of the finest in the world. Mr. Beloe.

. J. F. FLANNERY said it was astonishing that the important Mr. Flannery. ɔt of ferry-boats had not been publicly discussed before. It fortunate that it had been introduced by one who had had ience for many years as the managing engineer of one of the st ferry traffics in England, that of the Wallasey ferries. He reat diffidence in attacking one or two of the Author's sugges- . Starting with the assumption that the up-river Thames o was much more dangerous than the below-bridge traffic, Carson complained of the want of subdivision in the small above bridge, and also of their cabin accommodation. Any who had read the report of the Thames Traffic Committee, or evidence given before that committee, or any one who had l the statistics just given by Mr. Ravenhill, could not avoid ng to the conclusion that the danger of collision above London ge was almost *nil*, in comparison with the danger below lon Bridge. With regard to the suggested improvement in abin accommodation, there was at least one objection to it. e weight of the passengers were raised, would the vessels, their limited beam—limited as Mr. Bramwell had described— sufficient stability? On the Mersey, the weather to which the nger was exposed was sometimes very rough. In the upper ies of the Thames there was a sort of omnibus traffic: the ngers went on board for a five or ten minutes' transit, and r, unless driven below, left the deck; so that, even in winter, whole load was upon the deck. If the load were raised, would boat have sufficient stability? Probably not; but without g into calculations it was difficult to say. Looking at all the ımstances, the boats appeared to have had a just balance pre- ed in their design, and the result of their working had proved they were thoroughly adapted to the traffic. With reference to boats on the Mersey, he might mention that the "Heatherbell" designed by Mr. Carson ten years ago, and she had been edingly successful. It was (as Mr. Thornycroft had pointed a little remarkable that she carried so large a proportion of engers in comparison with her displacement, as contrasted ı the "Claughton." She carried nine hundred passengers, with splacement of 280 tons, so that for each ton of displacement had 3·21 passengers. The "Claughton" had only 2·53 pas- gers for each ton of displacement, and the "Lord of the Isles" 3. The "Heatherbell," which was considerably longer than the laughton"—eight beams instead of five—had performed her

Mr. Flannery. work for ten years at that rate, and her great success showed very strongly the authority with which the Author was able to speak. With regard to the question of the absolute safety of river steamers with a horizontal deck—the power of withstanding almost any collision—it would be remembered that the "City of London" not long ago had a violent collision with a German ship. He had had the opportunity of surveying that vessel closely, and the damage done to the bow of the colliding vessel, by reason of the horizontal deck of the "City of London," was something that could hardly be believed without being seen, especially when taken in comparison with the small amount of damage done to the iron deck of the "City of London." Bearing that in mind, he did not consider that it would be possible to construct ships that would be absolutely safe; but vessels would be made having much greater safety than they now possessed. It had been said that it was no use to have an immense number of water-tight subdivisions unless they were properly disposed. If, for instance, a vessel were put out of trim, so that the water could get down the hatchway, no subdivision could be of any avail. A vessel should be properly designed with regard to trim, and also with regard to longitudinal strength. The London Steamboat Co. were, not long ago, overwhelmed with proposals and designs for absolutely safe vessels; he believed something had been evolved which might come very close to absolute safety. At any rate, he was sure the Thames would hold its own against any other rivers with regard to passenger steamers. He had no doubt that the London Steamboat Company, under its present energetic management, would, in a short time, produce vessels well worthy of discussion at some future meeting of the Institution.

Mr. Donaldson. Mr. John Donaldson said he was of opinion that half a loaf was better than no bread, and he agreed with Mr. Flannery that if absolute immunity from danger could not be secured, an attempt ought to be made as far as possible in that direction. He thought that the problem of securing immunity from danger in cases of collision admitted of three general solutions. The first, and by far the best, was undoubtedly to avoid collision; but as that was a matter which interested captains and those concerned in navigation more than constructors, he did not propose to say much about it. The second consisted in arranging the materials of the structure so that the work of the collision might be taken up in destroying that which would not be essential to the safety of the vessel. Placing a sponson round the vessel, as proposed by the Author, was an example of that kind, and in river vessels which could carry a

Mr. Donalds

large amount of material in that way in proportion to their tonnage he thought it would answer, but not in the case of large steamers. But if the vessel to be struck could not be armed, something might be done by disarming the striking vessel. Some time ago at Portsmouth he witnessed a collision between a collier brig and H.M. steamer "Sprightly." The "Sprightly" was lying at anchor; the brig was drifting up the harbour broadside on, impelled by the wind and tide, at a speed of 3 or 4 knots per hour. On touching, the bulwark of the brig was carried away, and the bow of the "Sprightly" rose up over the angle formed by the deck of the brig, and her side, until the whole work of the collision was taken up, when she slid gently down again, and the brig was hauled out. That was all that happened; but had the "Sprightly" been fitted with a vertical stem, the brig would have been sunk. In this case the work was taken up in destroying the bulwark of the brig and in raising the forward end of the "Sprightly." He remembered another collision which took place in the Red Sea. The old P. and O. steamer "Valetta," then in the Egyptian service, was going down the Sea with troops for one of the seaports, and came into collision with another vessel, which struck her on the fore starboard sponson. She was cut down to within a foot of the water's edge; but so little was she hurt in any vital portion that she steamed back to Suez, was put into dock, and repaired, without any loss of life occurring. Here the work in the collision was taken up in destroying the sponsons, the deck, and part of the side of the "Valetta," and in destroying the bow of the colliding vessel. Another case had recently occurred, and was reported in the "Times." The "Herreschoff," torpedo boat, was out on a trial run with one of the second-class boats built by his firm. After the trial run, by some misapprehension, the boat was run into the steam-tug "Manly." She penetrated the "Manly's" side, and as she had an overhung bow, the penetration occurred above the waterline, and no great harm was done. He thought if merchant vessels were built with overhung bows, as in the case of the "Sprightly" (which was the fashion some years ago) a great deal of life and property might be saved. Unfortunately, he was unable to give an exact estimate of the value of the immunity from danger which might be expected from overhung bows. He had applied to the Board of Trade for permission to examine the wreck registers to see if he could ascertain the amount of life and property lost in collision through vessels with straight stems, as compared with those with overhung stems; but as the surveyors had not been instructed to report upon that matter, there were

Mr. Donaldson. no data upon which to form an opinion. He then wrote to the Board asking them to instruct their surveyors to send the required information in future reports. The reply was to the effect that the Board did not think it necessary to obtain statistics for the purpose of substantiating a fact which they believed to be generally admitted, agreed with him as to the value of overhung bows in cases of collision, and that therefore there was no necessity for obtaining the information sought. He wrote again, thanking the Board for the expression of their opinion, but pointing out that what he wanted was data for forming an estimate as to how much overhung bows reduced loss in cases of collision as compared with vertical bows. The reply, however, was still more unsatisfactory—the Board did not think they could justify on grounds of public utility the expense which would be incurred in the collection and publication of statistics of the nature specified. The third general solution consisted in constructing the hull of the vessel in such a way that, should she be damaged in a vital part, either the whole hull or the parts of the hull into which she might be divided would still float, and he thought that was best carried out, as in the case of the vessels in the Royal Navy, by a cellular construction; but from what he had heard as to the paying properties of river steamers, he was afraid that that could not be carried out. Something, however, might be done by way of compromise. The torpedo boats built by his firm were divided into six watertight compartments by five bulkheads, and between those were placed half bulkheads, rising from the keel to 6 or 8 inches above the level of the water, so that in the event of the hull being penetrated, and the water rising between any two of those half bulkheads, it might be possible for a man to go in and plug the hole up, and clear out the water by means of the pumps in the engine-room. Something of that kind might perhaps be adopted in the case of river steamers. It would be awkward, and would interfere with the comfort of the passengers below, no doubt, but he did not think there was much comfort at present in the cabin of a Thames river steamer. The difficulty of getting backwards and forwards might be overcome by having steps rising over those bulkheads, or by having a gangway along the centre with steps leading down to the floor, so as to reach the seats on the sides. Of course something in the way of a skylight would have to be constructed overhead. Possibly some of these suggestions might receive consideration in the construction of future steamers, but he thought decidedly that the idea of having overhung bows upon all merchant steamers was a good one:—All the naval men to whom he had spoken considered

that it was, and he hoped shipowners and shipbuilders would agree with them, and that the idea might be adopted. Mr. Donaldso

Mr. H. HAYTER wished to draw attention to a model of a light-draught iron steamer, of the most recent type, in use on the rivers of Eastern Bengal. As consulting engineers to the Eastern Bengal Railway Company, his firm had recently been called upon to order two steamers for the river navigation in connection with that railway, and he now exhibited a model and drawings of those steamers, and a photograph of the engines. Not being themselves experts in marine engineering, they had solicited the aid of Mr. Josiah McGregor, M. Inst. C.E., who held the important post of chief marine engineer to the Government of Bengal, and who had designed the steamers in question. They would, it was expected, attain a speed of 12 miles an hour, and were designed to carry goods as well as passengers. The length over all was 156 feet 6 inches; length between perpendiculars, 151 feet; breadth moulded, 22 feet; depth moulded, or from the underside of the floors to the underside of the deck amidships, 7 feet 10 inches; tonnage, builders' old measurement, 367 tons; draught, about 3 feet 6 inches. The engines were compound paddle engines on the diagonal principle; diameter of the high-pressure cylinder, 26½ inches; of the low-pressure cylinder, 46 inches; length of stroke, 3 feet. The steam was supplied to the smaller cylinder at a pressure of 80 lbs. His object was simply to draw attention to steamers of the most recent type introduced on the navigations of Eastern Bengal, embracing the rivers, Brahmapootra, the Ganges, and their extensive navigable tributaries—constituting one of the largest systems of inland navigation in the world, extending over hundreds if not thousands of miles. The steamers were now let under contract to Messrs. Hawks, Crawshay and Company, of Gateshead, at the cost of £5,100 each, delivered in London. This price excluded most of the woodwork, which would be supplied in India. Mr. Hayter.

Mr. J. N. SHOOLBRED desired to make some remarks in connection with the ferry traffic on the River Mersey, apart from the consideration of the form and construction of the steamers, and which referred more to the locality itself. It was stated in the Paper, that the circumstances of the Mersey traffic differed much from that on the Thames and on the Clyde, and that, while on the latter two rivers it was essentially up and down, and for considerable distances, on the first-named it was "cross traffic, and for short distances." On the Mersey it was concentrated at a single point on the Lancashire shore, whence the ferry-tracks diverged in a Mr. Shoolbre

Shoolbred. fan-shape. The Woodside ferry, carrying nearly eleven million passengers per annum, passed almost directly across the stream; the remainder inclined diagonally to it at different angles according to the length of their passage. The main up and down navigation of the river was therefore nearly at right angles to the ferry traffic. In addition, vessels, accompanied by their tugs, were constantly veering round either to enter or to leave the docks, on one or other side of the river. Then again, besides these sources of danger which were in motion, vessels were frequently at anchor in mid-channel, as the holding-ground was good in the neighbourhood of the great landing-stage. The area within which these impediments to navigation mainly existed was not more than 1 mile square. The dangers within this comparatively small space should, therefore, be diminished as much as possible, as the ferry service, particularly the most crowded one, the Woodside, had to be continued through the greater part of the night. The Author of the Paper had drawn attention to precautions which might be, and also which were, taken in the construction of the ferry-boats, and in their regulation and guidance; but there was one means as regarded the locality which would still further reduce the dangers. That was the illumination of the entire area at night by the electric light. Experiments for military purposes in France, at Chatham, and recently at Fort Monckton, had shown that it was possible to illuminate, by means of parabolic reflectors, a large breadth of surface horizontally. A series of such stations on both banks of the Mersey, and placed at a sufficient elevation to keep the direct beams of the electric lights out of the observer's line of sight, especially near the shore, would readily effect the object of illuminating the entire area. The band of light from each shore being fully able, on ordinary nights, to reach at least half across the river; while lights of lesser intensity might be used to illuminate the landing-stages. Indeed the entire Mersey, in its course from the Rock lighthouse to the Dingle Point, might be thus made clear; and on the shore the several landing-stages, the entrances to the different docks and points of approach, might each have special and minor illuminations. No signal electric lights should in this crowded locality, in Mr. Shoolbred's opinion, be placed on the ferry-boats or other vessels; as this would rather tend to increase the confusion, owing to the difficulty of judging the distance of these bright lights in motion. This remark must not, however, be taken as prejudging the case of the use of the electric light at sea for the mast-head and for the side-lights of vessels. There the conditions were widely different, and must be considered

by themselves. The objections now raised as to "too brilliant a light," and as to "intensity of surrounding darkness," &c., would probably disappear with time as the eye of the mariner got more accustomed to it. Proper precaution should also be taken to prevent bright lights of this kind being mistaken for those from lighthouses. This might easily be done, by causing each of the latter class of lights to have some distinguishing feature; according to the method being gradually introduced by the Trinity House, or according to that suggested by Sir William Thomson. Another objection which had been raised to the electric light was its not piercing a fog, and its so-called deficiency in this respect in comparison with other lights. Not many months ago Professor Tyndall, in the discussion on Mr. Douglass's Paper, "On Lighthouse Illumination by the Electric Light,"[1] had shown that the penetrating qualities of the electric light were proportionately quite as great, if not more so, as those of any other light; and he had referred to the labours of Professor Draper to confirm his view. The proportion of nights, even on the Mersey, when fogs prevailed, was, however, so small that they need not be considered in dealing with the question. Some experiments were carried out a few months ago by the British Electric Light Company near the great landing-stage to show the projecting power of the electric light on to the River Mersey; and Mr. Lyster, M. Inst. C.E., the engineer of the Mersey Docks and Harbour Board, contemplated, it was understood, lighting some of the dock entrances with electric light. But it was a general illumination of the entire river, as suggested in the previous remarks, which was needed. An illumination of this kind was equally applicable to all narrow and crowded waterways; such as the Thames, where it would be desirable for some distance both above and below London bridge. Mr. Shoolb

Mr. J. Fernie said there was a capital service of omnibus steamers upon the Seine; they plied between the fortifications, thus going right through the centre of Paris. There were fourteen stations, and the distance traversed was about 7 miles. The steamers were between forty and fifty in number, and they were built with raised cabins at each end, and there were only a few steps to descend to get into the cabins. By means of the break thus formed by the cabin's deck, passengers were sheltered very much from the bleak winds. The boats were exceedingly comfortable, pleasant, and clean; they were propelled by screws, and had upright high-pressure cylindrical boilers. The captain Mr. Fernie.

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. lviii., p. 158.

ernie. steered and communicated with the man at the engine by an india-rubber tube, so that he had full command of the vessel. The boats carried from one hundred to one hundred and fifty passengers. The great object seemed to be to make the boats ply as continuously as possible, and they ran in the summer every few minutes. The great defect in the Thames boats was that they were too large—nearly as large again as the Paris boats. Paris was splendidly supplied with omnibuses, yet the comfort and convenience and a pleasant sail on the river attracted a vast number of passengers. The navigation of the river was rather difficult. Near the centre of the town the river was encumbered with floating laundries, baths, and obstructions of various kinds; the river itself was narrow; some of the bridges were old, and had wide buttresses, so that when two steamers met there was often very little margin. The river was also rather swift, and altogether he considered that the navigation was more difficult than that of the Thames above bridge. The Thames was wide, the arches of the bridges were also wide, and the captain could see a long way before him; whereas on some parts of the Seine it was impossible to see for any great distance. Judging by the comparison of a paddle-wheel ocean steamer and a screw steamer, he imagined that the Paris boats worked at a third of the cost of the Thames boats. The crew of the Paris boats consisted only of a captain, an engineer, a ticket man, and a boy. Reference had been made to the competition of the omnibuses in London interfering with the river traffic; but in Paris the omnibus competition was still greater, for the omnibus system there was one of the best in the world. Instead of starting from a public-house, and stopping at public-houses, the omnibuses took their departure from great central points, stopping at comfortable offices where the passengers could take tickets for the next omnibus, and sit down while they were waiting. It was melancholy to see in London this public-house system adopted wherever people were likely to stay a few minutes; and he was ashamed, as an Englishman, to hear it stated that the boats could not be supported without the introduction of a bar. The uniform fare charged on these boats for all distances used to be $1\frac{1}{2}d.$, now $1d.$; a similar distance by omnibus or tram would cost $4\frac{1}{2}d.$ to $6d.$ The boats were well filled. Ladies and gentlemen, summer and winter, were found on the decks and in the cabins, and the boats managed to pay without a bar. The finest river steamers in Europe were those upon the Rhine—he referred, especially, to those above bridge. The highest compliment which the Germans could pay them was to call them

American steamers. They were not, however, made in America, nor on the Clyde, but on the Thames, and they did great credit to the Thames shipbuilders. Perhaps they did not come up to the American steamers in their great variety of comfort and convenience; but for ordinary day passenger-steamers, they were all that could be desired. He did not agree with the doctrine that had been propounded, that although life was very valuable, it was possible to buy it at too dear a cost—that doctrine he considered was a very dangerous one to advance in the Institution of Civil Engineers, and while it was wrong in principle, it was also untrue in practice. It was said twenty-five years ago that the safest place for a man to be in was a railway train, and yet, since that time, there had been many inventions and improvements for the saving of life; steel tires fastened on and made part of the wheel, the lock system in regard to points and crossings, the block system, and the like. Similar improvements had been made in the construction of steamboats. He had recently visited the "Orient," and had been delighted with the wonderful applications of science exhibited in her construction. The only thing that seemed to him to have made no progress was the penny steamer on the Thames. Even the system of communication, which had been described as so perfect, was as far behind the age as the steamer itself. With regard to the American steamboats, the reason why they had naturally adopted the "end on" principle was that they had such facilities in consequence of the tides rising so little. While there was a tide of 32 feet in the Mersey, in New York the rise and fall was only some 6 or 7 feet; so that there was none of that great pressure from the current of the tide, turning the steamer away from the pier to which she was moored. He had, in 1876, travelled in a steamer similar to that which had been described as now being made at San Francisco, but not so large. He had come from Boston to Harlem river, New York, by a train which was there run on to a huge ferry-boat; the train had six Pullman cars, three of which were put on one line of rails and three on another, in ten or fifteen minutes. As soon as the cars were fixed the announcement was made that dinner was ready, and the passengers dined in a large sumptuous dining-room carried over the tops of the carriages. As they sailed along they had a fine view of the city of New York; down the North River and across the Hudson to Jersey city, where the cars were put on the line for Philadelphia. He did not attach much value to the arguments on the ground of expense. It was true that the "Grösser Kurfürst" and other great iron-clads had gone down when they had

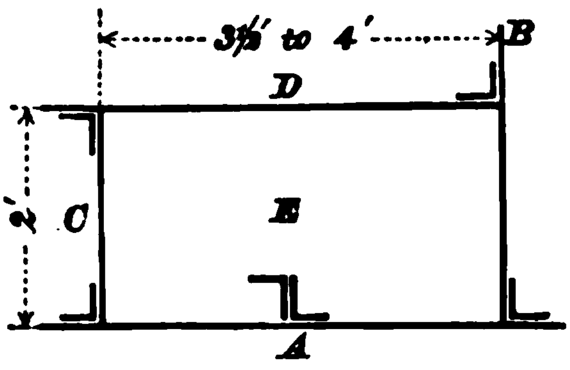
Mr. Ferni

ernie. touched one another; but they were made for the very purpose of striking and sinking one another. No one would think of making penny steamers with prows to enable them to run one another down. Within the last few weeks an instance had occurred of a ship dashing at full speed into an iceberg, and then striking it a second time; yet the vessel did not sink, and the passengers were safely landed at Halifax. Those who had crossed the Atlantic and remembered the intense fogs that sometimes lasted for two or three days and nights, so that it was impossible to see the length of the ship ahead, and remembered the immense advance that had been made in marine engineering, could not but look forward to the time when the Thames steamers would be made so strong and safe that they might run against Blackfriars bridge without going down.

e Rusett. Mr. E. W. De Rusett was glad that the discussion had turned upon the question of safety. The Author had begun with bulkheads, gone on with sponsons, and finished with handiness; but he thought it would have been better if he had begun with handiness in order to avoid collision. In the different drawings exhibited he did not see any special provision made for handiness. With this object he would direct special attention to the remarkable boats turned out by Messrs. Thornycroft, in which the keel rose at each end. In the case of a vessel 395 feet long, which had been lengthened 80 feet under his superintendence, he had raised the keel at the ends only 16½ inches, and she steered equally well with her old rudder, notwithstanding her additional length. What was chiefly wanted was an easy steering craft. Mention had been made of hydraulic steering-gear; but he hoped it would not be used on the Thames without some thought, because he had recently heard of such gear getting frozen and the pipes bursting. With regard to sponsons as a means of safety, he thought if they were put on at all they should not form part of the vessel's hull, because then they might be knocked away without injuring the main structure. The Americans were in the habit of projecting the deck far over the side, with struts underneath for support where it overlapped. In reference to safety by watertight bulkheads, the centre line longitudinal bulkhead system would require a vessel to be divided into very small parts, otherwise she would get seriously out of trim if the water found its way into her. This difficulty might be overcome by the two fore and aft bulkheads advocated by Mr. Mackie. The decks would be well supported, a clear space left without pillars in the middle of the ship for cargo, and the wings would be available for coals, stores, &c. With

athwart-ship bulkheads alone it was easy to arrange a steamer so Mr. De Ru
that if one compartment was stove in she would not sink; but it was well so to arrange matters that if the vessel were struck on a bulkhead two spaces might not be knocked into one, and probably cause the loss of the vessel. He exhibited a diagram (Fig. 4), in which the line A represented the ship's side, B the ordinary transverse bulkhead, and C a bracket frame, say 2 feet deep. The plate D was to be riveted to the ship's side at about the floor heads, to the bulkhead B and bracket frame C, so as to make an internal and separate watertight space, E. A somewhat similar design was made in 1860, for a different purpose, by Mr. J. Carr. Mr. De Rusett suggested that form, so that if a vessel was struck, either in the forward or the after part of a bulkhead so constructed, the water would either get into the intermediate space E, or to the after or forward compartment, and hence it would be difficult to ram the two compartments into one. This addition would also add to the strength of the vessel and bulkhead without displacing much cargo.

FIG. 4.



Mr. J. B. REDMAN said, the Gravesend steamboat traffic of past Mr. Redm
years was a remarkable example of the diversion of river traffic by the railway. Going back to 1821, twenty-seven thousand persons were landed at Gravesend in the course of that year. In 1845 the number had increased to one million and three quarters. The town itself was duplicated, also the steamboat companies and the piers. A score of large steamers were employed in the traffic, but when the railways were completed, the companies, after contending for some time against them, were dissolved, and the boats sold. The two piers went into Chancery, and the Town pier was now a ferry pier, the Terrace pier affording a look-out house for pilots, and it was occasionally used by royal and other distinguished persons for landing and embarking; but even that was now circumscribed by the opening of a new route by Queenborough. Mr. Ravenhill had spoken in no exaggerated terms of the merits of the Gravesend steamers, of which eight or nine belonged to each of the two companies, and two to the railway company. They were unequalled in point of speed, beauty of form, and deck and saloon accommodation, but they were the antitypes of the "Princess Alice" class of steamer. The saloon accommodation was all below water. They were not only good river boats, but were also good sea boats, as their ultimate fate would show. He had taken the

Redman. trouble to inquire into that subject, and one of the builders, Mr. Sidney Young, had written to him: "Our old firm only built one of the Star line, the 'Mercury,' and she was launched nearly forty-six years ago." Mr. Young further stated that he did not know what had become of her. Messrs. Arnold and Co., solicitors, of Gravesend and Lincoln's Inn Fields (Mr. Arnold being son of the manager of the Star Company), stated: "We sold one or two of the Star boats to Mr. Churchward, for light mail service over the Channel; the others went to Scotland, to the Clyde, and elsewhere." Mr. Hilder, solicitor, of Gravesend, who was in partnership with the clerk of the Star Company, stated that no one knew what had become of the boats. Mr. Quaife, manager of the Town pier, under the Court of Chancery, had sent the best account of the fate of the old steamboats. From this it appeared, of the Diamond Company, engined by Seward and Co. and the Penns, and of the Star Company, mainly engined by Miller, Ravenhill, and Co., that the following was their ultimate fate, viz.:—

DIAMOND COMPANY.

Diamond.—Sold. Broken up.
Ruby, Sapphire.—Sold to General Steam Navigation Company.
Emerald (new).—Sold. Converted to a schooner.
Ditto (old).—Sold to Licensed Victuallers' Company, and ran to Boulogne.

STAR COMPANY.

Medway.—Broken up.
Comet.—Sold. Ran from Hartlepool to Sunderland.
Mercury, Star.—Sold to General Steam Navigation Company.
Jupiter.—Sold. Ran from Dover to Calais.
Venus.—Sold. Ran to Guernsey and Jersey.
Satellite.—Sold. Went to Liverpool.

Having an intimate knowledge of the traffic on the Thames, he was prepared to endorse all that had fallen from various speakers as to the admirable manner in which the above-bridge boats were navigated. The style in which the boats were brought alongside the piers was unequalled; but in all other respects the service had deteriorated. With all its drawbacks it was a popular mode of transit with the masses, but (now that it had fallen into the hands of a very few persons) from the utter absence of discipline and cleanliness it was tabooed to a large class of the community, although it might be made as popular to them as the masses. It had been urged that large saloon steamers were not adapted to the above-bridge traffic, and there was some reason in the objection, as might be seen from the difficulty experienced in bringing up one of the larger boats plying to Greenwich and Woolwich alongside a pier in a heavy gale of wind and in certain states of the tide; but

Mr. Redman.

when it was considered that the boats themselves had been nearly stationary, and that the river above bridge during the last forty years had been developed 30 per cent. in regard to total carrying capacity, the objection did not appear to be tenable. Of that statement there was a standing, or rather a floating proof, in the existence of a new fleet of steamers that made the entire voyage from the Tyne to the head of the metropolitan river-traffic above Vauxhall bridge, discharging their coals there to save lighterage. Those steamers were 1,000 tons burthen, and drew 8 feet of water; they were flat-bottomed, and the spars and funnels folded down upon the deck. That was a sufficient proof that large steamers might, if required, be introduced into the upper reaches of the Thames. It had been urged by those interested in the above-bridge steamboat companies, that screw steamers were not adapted to navigate the upper parts of the river, on account of the difficulty of bringing them alongside the piers as compared with paddle steamers. The model described by Mr. Taylor with four screws appeared, to a certain extent, to remove that objection. One of the most serious drawbacks to the navigation in the upper river was that no improvement had been made in the mode of embarking and landing, which was the same as it was thirty or forty years ago. If paddle-boxes were done away with there would be many opportunities of improving the mode of landing. At present, the sponsons of the river boats were so small, and at so acute an angle, that it was often difficult in a gale of wind, or with the tide in a certain direction, to get the rolling stage on to the sponson. The rolling stages themselves were the same primitive things that they were forty years ago, running upon wheels something like the end of a cotton-reel; and an enormous amount of time was wasted in getting people on board. At Gravesend he had had some stages constructed of light wrought iron, with open battens, and mounted with large wheels; they were of very great assistance, being more easily moved and affording a wider gangway. Stages of that kind might be introduced for the upper river, which would allow persons to pass two abreast. With screw steamers it would be possible to have, now that the landing dummies were all of one regular height, bulwarks which would drop in sectional lengths (the deck of the vessel being always kept above the dummy), so that people might pass over in a mass instead of being throttled through the narrow gangways. He thought every one would admit that the community at large was much indebted to the Author for having in his interesting Paper ventilated a very important subject.

(Admiral Selwyn.)

Admiral SELWYN said that as an old seaman he had paid attention to the changes which were gradually taking place in the form of river steamers. He had for years believed that no speed could be got out of a vessel that did not resemble a plank set on edge, and that the more nearly she resembled a plank set on edge the faster she would be. That was not doubted for a moment by those who studied Beaufoy's experiments; but Beaufoy never recommended that a deck cargo should be put upon such a plank. If it was desired to construct a vessel, which should offer as little resistance as possible in its motion through the water, and should yet be capable of carrying in safety on deck a large number of passengers without any of the accidents that constantly occur from the heeling over of a narrow vessel due to the rush of passengers to one side, those difficulties would be obviated by cutting away the fore-foot, cutting away the heel, and widening the beam. That led to the question of the proper shape to be adopted. Looking at the bottoms of some of the newest vessels, it would be found that they were of the spoon shape,—the shape which the Americans had long since adopted, having necessarily to carry a heavy deck cargo with saloons and passengers. That it added to those conveniences the power of turning, which was essential to rapid manœuvring, was only an additional proof of the fitness of the structure for the purposes for which it was designed. Was there any good reason, in regard to the expenditure of fuel or in any other way, for believing that those vessels would be more expensive to run? because the whole question was how to pay dividends, how to run the greatest number of passengers at the smallest expense and with the greatest safety. Those objects were to be obtained above bridge as well as below bridge, mainly, by first attending to the form of the structure. In the form of a sphere elongated into the shape of a spoon would be found the greatest safety, the greatest carrying power, and the greatest power of division into compartments without injuring the general qualities of the ship. Great speed could be attained, and the athwart-ship compartments under those conditions, would give large spaces between them. It was very easy to expose the fallacy of the longitudinal bulkhead, because the instant the water got into one side of a ship longitudinally divided she lost her trim, and as soon as the trim was lost sufficiently, the hatchways, which opened into both sides, secured her sinking. In the case of one compartment in one of the modern long ships being filled, particularly if it were the centre compartment containing the engines, one speaker had stated that it was a question of the weight of the water

that got in; but he had forgotten that it was the unsupported weight of the engines and everything else inside. The flotative power of the two ends then only contributed to break up the structure. That was the true way of looking at the subject. Having a good form and dividing it judiciously, the next question was how thin ship-builders might, with perfect safety, make the skin. Sailors would rather have two skins of $\frac{1}{8}$ inch, divided by 6 inches space (if it were necessary to divide them only by 6 inches), than one skin of $\frac{1}{4}$ inch. A little accident might occur to break through the outer skin, but it was generally certain that the inner skin would not be broken through. He did not know a more magnificent instance of the added security of large ocean steamers by a double skin than that which occurred on one of the voyages of the Great Eastern, when she was struck by an ice-floe for 160 feet of her length, and when, owing to her cellular construction and her skin of 18 inches, she was saved, and continued her voyage. Of course a space of 18 inches for river boats was not always wanted, nor was it always requisite to be able to get inside, but sufficient facilities were desirable for separating the outside from the inside skin of the ship. Under certain conditions, Prof. Barff had taught all who chose to learn how entirely iron or steel could be prevented from decay from salt water. It had been said that such things had been tried and failed. How tried, and by whom? Who had made that which Prof. Barff only professed to make after long experience, and how had it been tried? There was no conclusive evidence whatever on the subject. All that was known was that whenever perfect peroxidation of iron or steel had been obtained, no inferior oxidation could take place. Some would ask how the rivets could be dealt with? There were plenty of protective fluids which would entirely meet the question of riveting; but it was not generally at the rivets that the great danger was encountered. There was ordinarily a double thickness there, and it was not there that damage was apprehended. Violence might sometimes tear through the rivets; but the great evil to be feared in steamers built of metal was the sudden attacking of one or two plates between wind and water, generally by galvanic action. He presumed that the Institution of Civil Engineers was devoted to progress and improvement; but many of the speakers had virtually said, "So long as somebody else improves, and I am at liberty to take his improvements, well and good; but if you ask me to improve, all I can say is that I have done the best I can for myself, and nobody can do anything so well." That was not the

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spirit in which great institutions—lying under the shade of Westminster Abbey—should look upon the subject. The nation would continue to commit great sums to the charge of those Institutions so long only as it was satisfied that reasonable progress was being made. Engineers ought to be the last to say that there was any finality whatever. They had provided (and he had contributed to some of them) great improvements in economising fuel, in the use of steam power and in other ways, so that they were enabled to conduct traffic at the required speed; and he believed that all the luxurious requirements of the day could be given at a low price, if only progress were allowed to have its legitimate development. But so long as for any reason those things, instead of being inquired into closely, were kept in the background and looked upon as inimical, further progress would not be made. Improvements were going forward rapidly in America, and Englishmen would be beaten if they did not also go ahead. Reference had been made to a steamer built at San Francisco, 400 feet in length and nearly 200 feet in width, and he wished to draw attention to the enormous carrying power obtained by the spherical shape carried out on those dimensions. He had himself devised a man-of-war, 400 feet long, 200 feet wide, and 18 feet draught, with a capacity of 16,000 tons under water, so that she could carry twenty 80-ton guns comfortably with all their stores and have another capacity of 16,000 tons above, although she was only 8 feet out of water. In those forms lay the power which was sought. The gain might not be so remarkable where the dimensions were cut down to those possible on a river; yet they might afford a measure of the advantages. The engine power of the American steamers was about 8 indicated HP. per square foot of mid-section for a speed of 20 miles per hour on a draught of 6 feet. They might appear to be very poor models above water, overburdened with cabins and with everything that would make a wind resistance; but they attained a very great speed per indicated HP. employed, which, after all, was the true test. In spherical-shaped ships it would be well to remember, as had been pointed out, that one should not expect with a certain frictional surface to get a much better effect (although there were beautiful under-water lines) than was due to the same number of square feet of frictional surface in any other shaped ship; but there would be the advantage of the tonnage. About 0·308 HP. per square foot of frictional surface sufficed to drive a well-shaped ship at 16 knots per hour. Mr. John Elder, who had tried the experiment, found that there was no difference between the resistance to

gress of a fine-lined, deep-keeled, narrow model, and that of Admiral Selwyn.
pherical model of equal tonnage. He desired to draw attention experiments[1] that had been recently tried by Mr. Gwynne wing that the hydraulic propeller gave 2 tons of push for every) indicated HP. That was exactly the same as with the ddle and the screw; but the hydraulic propeller enabled one deal with river-boats in a way that was impossible with either ddle or screw; it did away with all idea of sponsons or anything the kind; it facilitated the approach to piers and the passage board the ship; it enabled the vessel if grounded in shoal water clear away the shoal and get off in a few minutes; and it had additional advantage in case of serious damage, such as would npel instant beaching in any other case, of enabling the water be pumped out. He strongly pleaded for the further consiration by the Institution of the problem involved in prolsion by reaction. Another experiment on the reactive force a jet was made by Mr. Thornycroft, and he was partially the eans of getting it tried. Sir Isaac Newton was the first to ate that the reactive effect of any jet issuing from the bottom a column of pressure was double that due to the column pressure. The late Mr. Gravatt, M. Inst. C.E., had devoted nsiderable time to proving the same thing by figures; but e idea was discredited, and it was looked upon as utterly apossible. Within the last few months the matter had been nsidered by the Admiralty, and Mr. Thornycroft, when he eard the objection, said, with his usual practical common sense, "What is easier than to try?" He had accordingly rigged up copper tube in his yard, and weighed the reactive effect against set of weights in a scale; and he found that the statement was absolutely true that the reactive effect was double that lue to the column of pressure. This was a motive power which would act at all times, not subject as with the paddle to olling one wheel out of the water while the other was deeply nmersed in it, and not subject to be pitched out of the water ke a screw—a power which would take the above-bridge steam-

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[1] At Ferrara, Italy, each of eight centrifugal pumps, by Messrs. J. and H. ynne, discharges 57,000 gallons per minute, total 456,000 gallons, 7 feet 3 inches th, or 656,640,000 gallons per day. The river Thames discharges 362,000,000 llons per day. The best information on the hydraulic propeller will be found various Papers in the Journals of the Institution of Naval Architects, and the ited Service Institution, the last Paper being one on the most powerful nclad, in the discussion on which Admiral Sir George Elliot gives the results the last trials of the "Waterwitch."—J. H. S.

Admiral Selwyn. boats into the open ocean without feeling the motion and preventing the effect of the engines being the same as before. He thought that the subject was deserving the closest attention of the Institution.

Mr. Hollingum. Mr. GEORGE HOLLINGUM was pleased at the turn the discussion had taken in regard to the longitudinal system of bulkhead. He agreed with Admiral Selwyn that double skins presented great advantages. He believed that if the "Princess Alice" had been constructed as Mr. Mackie had proposed she would not have gone down, because there would not only have been the second skin in tension on the side struck, but two skins on the opposite side in compression assisting, thus affording time for putting the vessel ashore.

Mr. John. Mr. WILLIAM JOHN thought one point had not been made sufficiently clear in the discussion with reference to the division of light-draught steamers into watertight compartments. It had been said that it was very difficult to divide them because it was required to save weight; but, as a matter of fact, some of the very best divided and safest vessels afloat were vessels of very light draught; indeed, he would go so far as to say that the lighter the draught the easier it was to divide a vessel into watertight compartments, and to make her safe against sinking by the bilging of one compartment. In the case of a vessel of 2-feet draught divided into eight compartments by transverse bulkheads, if one of the compartments were bilged, practically the vessel would be sunk only one-eighth of her draught, or 3 inches; so that if there were a bulkhead or a partial bulkhead coming up a foot or so above the water, the vessel would be absolutely safe against being sunk by that compartment being bilged. Of course, getting nearer the ends of a vessel the trim would be altered by a compartment being filled, and it would be necessary to carry the bulkheads, or partial bulkheads, higher up, or to divide the vessel into shorter compartments; but it was easy to prevent a very light-draught vessel sinking by either one or two compartments being bilged. Mr. Donaldson had pointed out that it was not necessary, in order to render the vessel safe, to carry up the bulkheads to the deck and absolutely shut off the compartments one from the other, but that by deep floors or partial bulkheads all the required safety could be obtained; he also pointed out the difficulty created by taking the bulkheads through passenger cabins. Mr. John ventured to say that passenger cabins of vessels intended for still-water traffic should be entirely above water, and might be there without the slightest difficulty. One objection raised to this was

the want of stability; but in a vessel intended for smooth water a greater beam could be given, and indeed plenty of stability could be obtained from a comparatively small increase of beam without any material increase to the resistance of the vessel. Another objection mentioned by Mr. Bramwell was that with an increased beam it would be more difficult to go through the arches of bridges; but if paddle-wheels were done away with it would be possible to have considerably more beam and greater stability, and yet to go with more ease through the arches of bridges than the present boats could do. As a naval architect, he thought that the Clyde boats stood far higher in point of constructive skill, and as illustrating successful naval architecture, than either the Thames or the Liverpool boats. The Liverpool boats displayed considerable skill and (unlike the Thames boats) a common-sense adaptation to the work to be performed, which was chiefly ferry work. He could not help thinking that the original designer of the Thames penny boat must have had in his mind the model of a large ocean-going yacht, and simply adopted it on a reduced scale. If it were required to produce a vessel that had a minimum of deck room, of cabin accommodation and comfort for passengers, and the maximum difficulty of going through the contracted arches of bridges, no better example could be found than the Thames river boat. Mr. John.

Mr. W. H. CUTLER remarked that he had had considerable experience, principally as a passenger, of steamers on the Elbe, the Meuse, the Rhine, the Moselle, the Thames, the Seine, the Tyne, and the Mersey, and he should also mention some beautiful little passenger steamers on the Alster basin at Hamburg, from which he imagined the passenger steamers now plying on the Seine at Paris must have been copied. The Citizen and Woolwich boats on the Thames were the most uncomfortable and dirtiest passenger steamers he had found anywhere, except, perhaps, the steamers which crossed the mouth of the Seine from Havre, and ran up the River Orne to Caen. The London boats had only two good points about them—one, that they were splendidly handled, and the other that they afforded every possible facility for jumping overboard if anything went wrong. They were not fast, and they hardly afforded any protection from the weather unless the passenger chose to be stifled in a miserable cabin. They were wasteful in fuel, and no improvement seemed to have taken place in their machinery during the last thirty years. As long as eighteen years ago he remembered some twin passenger boats, the "Unions," on the Seine at Rouen, similar in construction to the "Castalia." Mr. Cutle

Mr. Cutler. Sixteen years ago a small steamer called the "Fury" ran between Rouen and Havre having the same kind of engines, and evidently made from the same patterns as the engines on board the Citizen boats on the Thames, but the engines had been modified, and a boiler suitable for a working pressure of 120 lbs. on the square inch had been substituted for the original low-pressure boiler. One of the cylinders of the engines had been converted into a steam-jacket for a high-pressure cylinder, which had been placed inside it, and which it therefore enveloped. The steam from the high-pressure boiler was conducted to the high-pressure cylinder, and when it had done its work there, it escaped into an exhaust-pipe, which was passed through the steam dome of the boiler for the purpose of superheating, and then was conducted to the low-pressure cylinder, and from thence to the condenser. This modification resulted in a considerable economy of fuel. He thought a good deal could be learnt from careful observation of the great many different specimens of steamers on the Seine, where compound engines were much in favour, and also spoon-shaped boats, not only with a spoon-shaped bottom, but also with a regular spoon-shaped bow. There were also a great number of luggage-boats called "Porteurs," with paddle-wheels hung over the stern; and also an extensive system of "Remorqueurs," or towing-boats, which hauled on a chain laid down in the centre of the river, by means of drums, which were worked by a steam-engine; the drums wound up the chain and relaid it as the Remorqueur passed on, dragging after it several barges of 1,000 tons burden each, and working, he believed, at a good profit.

Mr. Forbes. Mr. J. S. Forbes said he had been unable to follow many of the arguments brought forward by previous speakers. He happened to be one of those who had to find their way amongst much conflicting scientific evidence to a practical result. He had recently come to the knowledge that the Thames above bridge might be made a remarkable collecting ground for passenger traffic, and upon the strength of that conviction, and with the assistance of Mr. Barry, a railway terminating at a pier on the Thames at Fulham was being constructed. He was, however, at his wits' end to know how they were to provide a satisfactory means of collecting and delivering the traffic in connection with that pier. He had therefore come to listen to the discussion, to endeavour to pick up what he could upon the subject. He confessed to have been a little puzzled with the various opinions that had been expressed, and he did not know that he had heard anything quite *ad rem*, except that there were certain steamers

on the Seine and elsewhere which seemed to contain the germs Mr. Forbes. of what he wanted, which was a steamer somewhat differing from the Thames penny boats. He willingly admitted that, as far as mere handling was concerned, the Thames boat was a marvel of discipline and skill, but he did not think that it combined all the elements of comfort, cleanliness, shelter and convenience required. He was not particular as to the mode of construction, but he wanted a boat to comply with the conditions which he should prescribe as being necessary for the public service. She should draw but little water; be very handy, comfortable, capacious, cheaply worked, and as safe as was compatible with his duty to the public, or with Mr. Bramwell's notions as to what was practical and what was theoretical. He wished to make a suggestion to the Institution. Between, say Battersea bridge and Richmond, a particular thing was wanted which did not exist. Could the Institution direct the minds of rising engineers to invent something which would comply with the prescribed conditions? and would it be out of place in him as representing those who had a deep interest in the question, to suggest that a small premium should be offered to induce them to devote their energies to the subject? The river should be treated as a mere collecting ground in connection with the railway, and the problem should be, how to bring people from certain parts on the river to a railway station, in order that they might find their way into the interior of London in the cheapest, most economical, and most comfortable manner. In order to bring the matter to a focus, he would be happy to offer a premium of 100 or even 200 guineas for the best report or proposal on the subject, to be submitted to the Council for their approval.

Mr. JOHN ANDREWS, N.A., of Messrs. Westwood and Baillie, Mr. Andrews. observed that the Author of the Paper contended "that from collision alone need danger be apprehended, and its results anticipated in their design," and suggested as a precaution against this danger "division by bulkheads." Now a vessel, when intact, had a certain amount of shoulder or freeboard; that was, her power only to stand upright on the surface of the water, and if, in the event of collision, or other cause, any of the holds became filled with water, so much of this shoulder or freeboard might be lost as to render the vessel unstable and liable to capsize. What was meant by the shoulder or freeboard, was the angle contained between the line of flotation of the vessel, when in a quiescent state, and the line drawn to any angle of inclination. The weight of the hull acted downward through its centre of gravity, and always tended to overturn

Andrews. the vessel. The shoulder was the power that counteracted the effect of this downward weight, and tended to restore the vessel to her upright position; and that, the power of the overturning weight, was the momentum due to the weight through its centre of gravity; and the power of the shoulder was the moment due to the volume of the shoulder by the distance of its centre out from the middle line of the vessel. If the moment of the shoulder was greater than the momentum of the weight, the shoulder would have a surplus of righting power. But if the power of the shoulder were destroyed, the righting moment would be altogether lost; the weight would be forcing the vessel down; there would be no buoyancy to counteract this downward pressure, and the vessel would roll over. Thus, not only was a vessel in danger of sinking through collision by loss of her buoyancy, but also, even when the buoyancy was maintained, by loss of the power of the shoulder to restore her to the upright position. The latter effect usually happened before the former, because it took so little to destroy the shoulder and bring about instability, even where considerable precautions might be taken to prevent the vessel sinking. Attention might therefore be more particularly directed to the question of maintaining a reserve of shoulder, whilst at the same time considering the question of the maintenance of buoyancy. Now in River Steamers there was absolutely no prevention of this tendency to capsize in the event of their being in collision, and their holds becoming filled with water. Although watertight transverse bulkheads might be fitted to them, these would not prevent capsizing if the portion between any two of them became filled with water. In a vessel of 250 feet length and 25 feet beam, if $\frac{2}{5}$ the length were filled with water, the shoulder would be so much destroyed that the remaining portion would not be sufficient to maintain the vessel upright. Such a vessel when intact would have a buoyancy, if tolerably fine, of 470 tons; and a surplus righting moment of shoulder of 270 foot-tons; and if $\frac{1}{5}$ the length were destroyed, the vessel would sink deeper into the water in proportion to the $\frac{1}{5}$ of the length lost. This would be equal to a loss in the righting moment of 145 foot-tons. Thus by the $\frac{1}{5}$ deeper immersion 145 foot-tons would be lost to the righting moment of shoulder, leaving a surplus of 125 foot-tons; and if $\frac{2}{5}$ were destroyed, the surplus righting moment would be reduced to *nil;* the returning power would be gone, and the vessel would roll over.

Longitudinal bulkheads had been proposed, and had been worked along the sides of vessels to provide against the effects of collision;

but these bulkheads took up so much of the shoulder that in the event of collision, and the side divisions becoming filled with water, so much of the shoulder might be lost as to be fatal to the vessel; and although the transverse bulkheads might be tolerably close, still the space between them might be so large that injury to one compartment might cause the vessel's overturning. Now, to obviate the effects of collision; and to prevent this tendency to capsize, and to secure a positive reserve of shoulder and of buoyancy, these River Steamers might be constructed with air-chamber belts along the sides; which air-chamber belts might be divided into any number of smaller compartments by diaphragms, and not interfere in any way with the internal arrangements of the hull of the vessel. The air-chambers would be made of a capacity and buoyancy that would entirely float the vessel in the event of any of the compartments of the air-chamber belts becoming damaged, and all the hold or internal portion of the vessel becoming filled with water, and would give safety and protection to the vessel from overturning or sinking. In River Steamers some arrangement of reserve of buoyancy, and reserve of shoulder or stability, seemed to be required to prevent capsizing and sinking in the event of their being in collision, and their original buoyancy and shoulder becoming destroyed. Mr. Andr

Commander JAMES D. CURTIS observed that a previous speaker had suggested the cutting away of the fore foot. Mr. Scott Russell had said, "Cut away the dead wood aft in the heel." A vessel pivoted on her fore foot, and consequently it would be found that the statement of the previous speaker was wrong in principle. With regard to sponsons he would suggest that there should be a heavy rubbing or collision streak all round the ship to prevent such a collision as that of the "Princess Alice" proving so fatal. If, for instance, there was a heavy baulk of timber round the vessel she would have a much better chance in the case of collision. The London boats reminded him of the old ferry-boat to which he was accustomed when a boy, very few modern improvements having been adopted in them; they had not kept pace with the street and suburban traffic improvements. One of the late improvements adopted since the "Princess Alice" went down was the putting of tin boxes under the seats to be thrown overboard when they were wanted. He thought that something still further was wanted—something fastened to the boxes through which a person might put his arm and hang on. It would be also desirable to have a slight rod connecting two of them, because he believed that two so connected would keep eight or ten people breast high Command Curtis.

ander s. in the water. What boats they had, the oars in them were not secured by laniards; in event of their being swamped, in all probability the oars would drift away. A suggestion had also been made by a Mr. Reed, coastguard officer, with a view of showing the direction in which a vessel was coming round a point, or steering, the helm moving the red or green shade over the masthead light. He had seen the Rockferry boats at Liverpool with a screw and a rudder at each end. They were managed very well, and were easily got alongside. The captains of the London boats, however, objected to screw steamers, because they said they could not get them alongside the piers. He had no doubt that engineers could put speed into vessels with a large beam. The true form of a vessel, in his opinion, was that of a section of an egg, the transverse sections being in all cases semicircular. The stability of river boats should be greatly due to their being of considerable beam. For above-bridge boats he would suggest a spheroidal shape of which the length was 4 times the beam, and for below-bridge boats a length 5½ times the beam, with a rubbing streak 3½ feet amidships from the waterway plank, tapering off at the ends, with planking intervening. There should be awning decks for two-thirds the distance, and saloons with seats facing amidships, 2 feet or so intervening between the seats (a lane 2 feet wide). Screw propellers should work in tubes, one at either end, which would lessen the vibration, with a ball and socket jointed nozzle, to divert the water from the screws, in lieu of rudders, thereby facilitating the steerage. The vessel could then be made to move broadside on to the piers if required. The vessels below bridge should have an awning deck aft only. There should be no dead wood, or very little, as he imagined its use was principally for sailing vessels, keeping a steady course and holding a good wind. False elastic spring stems, or buffers, would be useful to lessen concussion. The present boats might be trustworthy end on, but he doubted it in a beam sea. The rubbing or collision streak should be arranged to prevent boats being swamped when the vessel rolled; possibly air-tight wings and braces and stays might be affixed to it. The scuttles should be higher, and pointing skywards. The Thames captains had no superiors in river navigation; they were civil, cool and collected, and handled their boats, such as they were, as well as it was possible for mortal to do so. But that was no reason why the boats should not be improved upon. They should be shorter, more buoyant and stronger, and pivot on their centre, and be able to move broadside on. A vessel should have appli-

Commander Curtis.

ances for floating all hands in case of emergency. The living telegraph, or call-boy, was a useful individual; he had his eye at all times on the captain, and he repeated the commands given by hand; ultimately he became a helmsman. Telegraphs by wire and chains and rods were apt to stretch and get out of gear, and the indicator did not then indicate correctly. The Ship Electric Telegraph Company appeared to meet all the requirements for sending messages. Paddle-steamers should have paddle-box life-boats ready for hoisting out at all times, and the crew should be exercised at times; paddle-boats pulled as well as any cutters of men-of-war, and they were prolonged semi-spheroids.

Mr. Carson.

Mr. W. Carson, in reply upon the discussion, said he regretted it had been supposed that a comparison unfavourable to the Thames had been attempted in the Paper. The peculiar circumstances of the Thames, and the land competition, were specially noticed. It was rather the object to enable those who had to do with river traffic to compare their practice with that of their neighbours; and to strengthen their hands as regarded the public by a favourable expression of opinion. He had suggested some modifications in the Thames vessels, but it was admitted that it would not be possible to construct such craft so that absolute safety in collision could be obtained. Mr. Bramwell and Mr. Ravenhill had argued that to attempt any more than had already been done was not necessary, looking at the small percentage of accidents; and was not reasonable, looking at the traffic earnings. The latter gentleman had, however, thrown some light on the first point. No opinion was ventured in the Paper upon the staff of the London River Company, but what did he say? He objected to the way in which the company's hands were tied up in choosing their men, owing to the restrictions of the Watermen's Company. Was it possible that he thought good luck had something to do with this immunity from accident, or why was he not content to leave "well enough" alone? Then, as to whether vessels more expensive in first cost would or would not pay, that was a duty to face if additional safety could be purchased in that way. But Mr. Ravenhill went further. He said old engines were put into a new hull to particulars supplied by the owners, for which the builders were not responsible; and the result had been embodied in the Paper and described as the type of a Thames river steamer. He implied a want of progress because builders were not consulted. These remarks were most valuable, and his concluding suggestions, if the river company were spirited enough

Carson. to carry them out, no doubt pointed to a thoroughly satisfactory class of vessel, which would enable the Thames to take the lead in the future as in the past. Heavy pressures, such as were indicated by Messrs. Perkins and Thornycroft, lighter machinery and probably screw propulsion, with the same displacement, would leave a sufficient margin, even in the smaller vessels, for that extra weight which a better bulkhead division would entail. Mr. Rogerson's experiments with the "Loftus Perkins" tended to the same conclusion. As to the form this extra weight was to take to secure the best results, longitudinal bulkheads had been found fault with on grounds which were stated and met in the Paper. Mr. Bramwell said they would unduly interfere with the use of the below-deck spaces; and other speakers suggested a loss of stability from weights being carried higher, and from unequal immersion. There was little doubt but that the draughtsman might safely be left to dispose of these objections: with a break for the cabins at each end the first would disappear; and a proper subdivision would satisfactorily meet the latter. Then as to the position of the steersman, it went without saying that the bridge, in the presence of the master, with an all-round look out, was the proper position; and the steersman's duties ought to be confined to his own work without the distraction even of the stern fender. Excellent, it had been said, was the call-boy arrangement, but the telegraph was at least as reliable; and it was also a labour-saving instrument; its use on that ground, if on no other, ought to be encouraged. Let the master have a telegraph, put the steersman in the very best position, and, by way of suggestion, the call-boy might be left to deal with the fender; so that without additional cost there would certainly be a not less satisfactory distribution of the navigating force. It had been mentioned as a matter for regret that the engines had not received more attention. No doubt that was a most important matter, though not immediately within the scope of the Paper; and the same of the material of which such craft should be built. Steel had been mentioned, but it was tolerably evident that it was not likely just yet to be used for the hulls of river craft. There was no margin for saving in a plate $\frac{1}{4}$ or $\frac{5}{16}$ inch thick (which, notwithstanding the comparison with brown paper, was generally sufficient); and a reliable countersink could not be obtained with a lesser thickness. He thought that the difference in cost between similar steel and iron plates would be expended with greater advantage in a superior bulkhead division. Some remarks had been made on cargo traffic, and the arrangements at Liverpool for end-on loading. Those arrange-

Mr. Carso

ments were perfectly suited to the traffic, and no difficulty whatever had arisen, even with the ordinary vessels, in working into and out of the embayment. The new piers and stages at Seacombe, which were on the point of completion from his designs, were intended to form the complement of the Liverpool facilities; and, together, would afford complete accommodation for cart and horse traffic across the Mersey. It was to be regretted that the boat, described by Mr. Beloe, which was to carry this traffic, had been built without special reference to the requirements, so that the immediate result would not probably be entirely satisfactory. The discrepancy between the displacement and carrying capacity of the "Claughton" and "Heatherbell" arose in this way: the "Claughton," a cross-river boat, had two pairs of engines, with sponsons of the full width all round; the "Heatherbell," a down-river vessel, had a single pair of engines and only partial sponsons. Mr. Donaldson had suggested half bulkheads. The Author had fitted these athwartships in several Mersey boats, with a great saving of weight. This was the principle of the longitudinal bulkheads suggested in the Paper. He did not think trusses for longitudinal strength necessary for ordinary lengths with a good bulkhead division. It had been said that if the machinery compartment filled, such vessels would break their backs. Here was a case in point; a sister ship to the "Water-lily," with a depth of one-twentieth of length, struck a wreck and filled amidships: the vessel had eight hundred passengers on board; the fires were put out, but she managed to steam ½ mile to a landing-place, where the passengers were disembarked, ignorant, until they had done so, that they had been in danger. The vessel remained afloat for six or seven hours until docked for repairs, and she sustained no injury beyond the local one. There could be no doubt that thorough bulkhead division saved many lives on that occasion. The discipline of the crew was also worthy of notice; although aware of what had happened, and not knowing what the result might be, no sign escaped any of them; panic might have undone all that the most perfect division of the ship could do to save them and the passengers. And in his experience this was a fair sample of the crews of Mersey river steamers. The use of water power for steering had been objected to on account of the risk of freezing. There was no risk on board a river steamer in this country, because the pipes could be perfectly sheltered. In exposed positions water pressure might be safely used when mixed in the proportion of 4 to 1 with crude brown glycerine. He had used this mixture, through uncovered pipes of over 300 feet

Carson. long, on an exposed pier on the Mersey, for six or seven years without freezing.[1] In more rigorous climates a small addition of methyl alcohol might be required to overcome the excessive pipe friction which would arise if a greater proportion of glycerine became necessary; but this did not apply to the British climate.

Correspondence.

Chanute. Mr. O. CHANUTE, Chief Engineer of the Erie Railway Company, furnished the following notes concerning the principal points in which the American differed from the European practice. The first general impressions produced upon an American by a European steam ferry, more particularly those of London and of Paris, were the small size of the boats, which were very long in proportion to their width, and that the cabins were below the deck. This of course resulted from the necessities of the traffic, and especially from the fact that in Europe the passenger business was separated from the cart traffic, while they were almost invariably accommodated upon the same ferry-boats in the United States. This concentration of both classes of traffic upon the same vessel was thought in America to result in several advantages. The boats could be made materially larger than they would be were the traffic divided, and were hence more economical in operation, as they required nearly the same crew, whether the vessel were large or small. The average loads sustained a larger proportion to the carrying capacity, as each class of traffic preponderated at a different hour of the day, the passenger transit chiefly taking place in the morning and evening, and the cart traffic being greatest in the middle of the day. The large size of the boats, moreover, admitted of the cabins being placed above the decks; they could thus be thoroughly lighted and ventilated, and in many cases were handsomely furnished. It should be explained, however, that the American ferries very seldom did an "omnibus business" in the line of the streams. Almost all the traffic went across, and the boats rarely plied between more than two landing points. A more important difference in the American practice consisted in the method in which the boats crossed the stream. In the eastern sections of the country, and on tidal rivers, they landed "end on" at right angles to the shores, and plied like shuttles between them. They thus crossed direct, they lost no time in turning, and were loaded and unloaded with great rapidity; the

[1] *Vide* Minutes of Proceedings, Inst. C.E., vol. xlix., p. 39, and vol. lii., p. 242.

Mr. Chanute

carts and passengers simply going on at one end, and off at the other. For this purpose the boats were made double ended, with a rudder at each end, and two pilot houses. One, or more frequently, two carriageways, about 10 feet wide, extended longitudinally from end to end of the deck, the cabins being placed outside of these, but sometimes overhead. To obtain space for these the deck projected beyond the hull from 10 to 15 feet on each side, the outside being flush with the outside of the wheels. The "slips" into which the boats ran were a little longer and wider than the boats, and were built of a double or triple row of piles driven deep into the mud. The piles sprung when struck by the boats. The shore approaches were provided with an adjustable floating bridge, the inner end being hinged, and the outer end supported by a pontoon; and to this bridge the boat was made fast by chains and large wooden bolts, which, in connection with the enclosing "slip," maintained her firmly at the landing. The hulls were mostly 120 to 200 feet long, and in the proportion of $\frac{1}{5}$ to $\frac{1}{7}$ of their length in beam (generally $\frac{1}{6}$), and drew from 6 to 8 feet of water. They steered well, and were quite manageable, but it was desirable that they should oftener be provided with watertight compartments. The engines were usually of the beam condensing type, placed amidships, and mostly below the deck; they were housed in, and the only portions exposed to view were the overhead walking beams and their attachments. The shaft was provided with a crank at its centre; it passed below the deck, and was attached to the side wheels, the steering being done altogether with the rudder. The cabins were placed over the projecting guards fore and aft of the wheels; they were well furnished, heated by the waste steam, and lighted with gas stored in a flexible india-rubber holder. These boats were certainly more comfortable than those of European ferries; they were generally provided with two lifeboats, and a large number of cork life-preservers stored under the seats. Although collisions occasionally occurred, they very seldom resulted in loss of life, the projecting guards affording an efficient protection to the hull, which was almost invariably built of wood. The range of the tides, in which these ferries operated, was about 5 or 6 feet. In some sections where the range was greater the approaches had been made upon a series of floating bridges, hinged end to end upon floats, which successively grounded upon a series of submerged piers, so as to preserve the same inclination of roadway on and off the boat at various stages of the tide. The boats crossed tide-ways in which the current ran from 4 to

Chanute. 5 miles per hour, and entered their slips without difficulty. In consequence, however, of their doing this "end on," it was probable that in a more rapid current than 5 miles per hour advantage would have to be taken of some indentation of the shore, or artificial protections built at the ends of the slips to preserve the boats from swinging upon entering or leaving them.

On the Mississippi, Missouri, and other western rivers, a different type of boat and approaches was used. The summer floods rising to a height of sometimes 30 and 40 feet above low water, the boats landed broadside against floating stages, connected by gangways to the shore, and moved in or out as occasion required. The boats were single ended, and landed with the bow up stream. The favourite mode of construction consisted of two hulls joined in a single bow, with the single wheel placed nearly amidships. This was driven by a horizontal high-pressure engine, forward of the wheel, and the boilers were placed on the main deck near the bow, and fired from the outside of their enclosing shelter. The boilers, engine, and wheel thus occupied most of the central portion of the boats on the main deck, and the cabins were placed overhead and surmounted by the pilot house. Guards projected beyond the hull on all sides, and upon these, all around the machinery, boilers, and wheels, a carriageway extended, upon which carriages and animals were driven, coming on from one side and going off on the other. A light railing surrounded the outer guard of the boat, gates being left at suitable intervals, and a light apron extending between the boat and the landing-stage. Oddly and crudely as these boats seemed to be arranged, they yet subserved an excellent purpose, were easily steered and handled, and accommodated a large business. They were from 75 to 150 feet in length, with a draught of 2 to 5 feet, and an extreme width of 30 to 40 feet, this of course including the projecting guards, and the space between the hulls. The lightness of all the work above decks conveyed an impression that the boats were very frail; but in point of fact the hulls, which were built of wood, were strong, and would bear a good deal of pounding on sand bars, and against snags and floating drift. During the civil war a number of ferry boats were transformed into gun-boats, and did excellent service in running past hostile batteries.

The peculiarities of the American systems, like those of the European ferries, had been dictated by the surrounding circumstances as well as by the character of the traffic to be accommodated. The conditions were so different in Europe from those which obtained upon western rivers in America, that no hint of

mprovement was likely to be derived from western ferry-boats. Mr. Chanute [he eastern feature, however, of landing end on, and of crossing he stream without turning, was believed to be more economical ınd convenient than that of landing broadside on, and there were loubtless several ferries in Europe where it might be introduced o advantage. It had been adopted as early as 1811, being lesigned by Robert Fulton for the first steam ferry-boat ever ›uilt, and had answered so good a purpose that no other plan was ıow used in the eastern tidal rivers of the United States.

Mr. C. W. Copeland, of New York, desired to direct attention Mr. Copeland o the following articles bearing on the subject of passenger iteamers:—"Iron hulls for western river steamboats;"[1] "Inernal navigation;"[2] "Light-draught, fast, stern wheel steam racht."[3] He also forwarded, for the library, a copy of the specifications and plans for a light-draught steamer for the Mississippi iver.[4] This was the first complete specification and plans of this :lass of steamer which had been published. The speed in still water would probably be about 12 miles an hour.

Mr. E. A. Cowper observed that the Paper gave a good deal of Mr. Cowper. information, particularly in reference to the Mersey ferry-boats; but it would have been of greater value had the information been more complete, for instance, if the pressure of steam had been given in all cases; but perhaps the Author would be good enough to supply this in his reply. The Paper, no doubt, was not a history of the boats on the several rivers, as nothing was said ıbout old boats now out of use; but it so happened that the Mersey boats had greatly improved from the time when they had ingle engines and a fly-wheel close to the inside of the boat, whilst the Thames boats had greatly deteriorated in consequence of the competition by railway; in fact, all the fine fast boats to Gravesend, Margate, and Ramsgate had been taken off. These were more fit to be compared with the large boats on the Clyde and Mersey, and were very fast. The circumstances of the three rivers were so different, that they necessarily caused the adoption of very dissimilar classes of boats. Many facts would have to be

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[1] "Transactions of the American Society of Civil Engineers," 1874, Paper No. lxv., p. 271.

[2] *Ibid.*, vol. vii., p. 393.—"American Engineering." The Paris Exposition of 1878.

[3] "Scientific American," Supplement, 1879, Nos. 172, 179.

[4] U.S. lighthouse establishment. Specifications for building the side-wheel steamer "Joseph Henry," 1879.

Mr. Cowper. noticed, particularly in reference to the Thames, if a sound judgment was to be formed as to the suitable character of the boats used above bridge; thus the height of the bridges above high water spring tides, the depth of the river at many places at low water, the width of the bridges and set of the stream through them, the character of the freight, and particularly the nature of the traffic on the river, which might interfere with the boats. The conditions of the traffic on the Mersey were peculiar, and very different to the Thames above bridge. There was often a heavy sea on, which in a gale was most violent, and there were ships of the largest class moving about, and anchoring just where they pleased, so that with a 6-knot tide there was no safety in stopping, as the boat might drift across the sharp stem of a large ship which might have just anchored in a fog, or the boat might be run down by a steamer five or six times the tonnage of the ferry-boat; indeed, during a storm, the ferry-boats were often much bruised. They certainly seemed now to be well protected with good timbers all round, and to be of a very handy shape for manœuvring, and being large enough for division by bulkheads, full advantage appeared to have been taken of them to render the boats unsinkable, and with a large amount of power on board there existed good means of avoiding danger when it could be seen. There was nothing to curtail their dimensions, but the necessity of keeping them of a handy size, and they necessarily were made large enough to take the cart traffic, and strong enough to bring up alongside the piers in a heavy sea. Now the traffic on the Thames above bridge was quite different, and he did not altogether agree with several parts of the Paper. The Author said, "assailants are to be looked for from all quarters above bridge." But was this the case? There were the large old-fashioned barges floating up and down, and now and then half-a-dozen of them in a line behind a steam-tug moving through the water; then there were a few small row boats, steam launches, and other river boats, but nothing of large tonnage moving about quickly, or crossing the path of the boats, which were not ferry-boats, but which carried passengers up and down the river, over a distance of about 12 miles; so that unless a boat were injured by running into a bridge, a barge, or a pier, no particular damage could occur, and should she spring leak by running on to an anchor, she was only a few yards from the shore, on which she could generally be beached without danger. The competition by railway had undoubtedly stood in the way of higher fares being obtained, and had of late years prevented much capital being invested in better boats and more powerful

es and boilers; but in order to meet the demands of the Mr. Cowper.
these boats had to be run at very frequent intervals, and
ore carried a moderate number of passengers; and, con-
ıtly, it would be worse than useless to make them large, with
ous saloons; and moreover the bridges would not admit of it,
he river would not float boats of much greater draught of
, though there was more depth of water above bridge now
here used to be. Possibly some advantage might be gained
placement by making the boats with more of a "spoon bow"
tern, and with very decidedly "flashing out" sides at the
-line, and particularly at the full-load water-line fore and aft
paddle-wheels. This would render them safer with a heavy
oad, the deck being carried out somewhat so as to increase
ccommodation. Then if the boats were also made of steel,
might be made lighter, as they were amply strong enough
and carry better boilers at a higher pressure, and much more
ful engines, so as to be thoroughly handy and faster. He
not agree with the Author in wishing to cut up the small
by a number of bulkheads, particularly by a longitudinal
ead, as this would have to be carried up a considerable
t to be effective when the boat should heel over from one
lling with water, thus cutting the small cabin up into two
hed narrow passages. The extra weight of more bulkheads
also be highly objectionable; he trusted no such paternal
l as that of a hard and fast rule for such a construction
ever be allowed on the Thames. He would add that he
l with the Author, that to some extent the tendency was
"the fares fix the paying engine power, and the speeds will
her or lower according to the weight to be driven;" and that
a point of great importance that the boats should be "well
engine control," as the increase of the engine power he
to be the key to improving the river boats above bridge.
greed also with the Author when he said: "No doubt their
ıers were somewhat hampered by the small dimensions of
oats, and the limited head-room under bridge; and for these
ıs, and also on account of its wind draught, the type of vessel
the saloon on deck is unsuitable." But the following remarks
the first page appeared to be very much to the point: "On
'hames above bridge, where short distances are traversed,
vessels of moderate speed and light draught, possessing
steerage power, and well under engine control, are used,
ppear to be well adapted to deal with the traffic of a re-
d and crowded smooth-water area. Under such conditions

Cowper. great strength of hull would defeat its object; great handiness is necessary, and when a choice must be made between strength to resist the force of collisions, and handiness in order to avoid them, in the latter quality lies the greater probability of safety."

Deas. Mr. J. DEAS remarked that the most recently-constructed steamer for the cart-and-horse traffic over the Clyde at Glasgow was of the following general description: Extreme length, 60 feet; extreme breadth, 35 feet; depth at sides amidships, 3 feet 10 inches; depth at sides at end, 1 foot 5 inches. There were hinged platforms at each end for the vehicular traffic, for which there were two roadways on deck; these platforms projected 15 feet from each end of the steamer. There was also a hinged gangway for foot passengers at each end. The steamer was worked by two chains, each $\frac{3}{4}$ inch in diameter, stretching across the river, and up a slip on each side, having gradients of 1 in 14. The engines two in number, were high pressure non-condensing, of the diagonal inverted type; the cylinders were 11 inches in diameter, and the length of stroke 18 inches. The two boilers were upright, 8 feet high, and 3 feet 6 inches in diameter. This steamer carried eight carts and horses, or four lorries and two carts and one hundred and sixty-five passengers, or five hundred and fifty passengers alone.

Evans. Mr. W. W. EVANS, of New York, observed that it had always been a matter of astonishment and delight to him to watch the skill with which the pilots of the Hudson river steamers, 380 feet long, drove their craft, at 20 miles an hour without break, through the Highlands, on a dark night when nothing was to be seen but a very faint outline of the tops of the mountains on each side, with a crooked channel ahead; and frequently encountering fleets of twenty to forty canal boats towed by a single powerful steamer, termed a "tow," six or seven of the grain or timber boats being on each side, and strings of them behind. There were turns so sharp in the windings of the Hudson river in this locality, that a stranger standing on the bows of a boat in daytime, within less than a mile of a bond, could not tell if the river turned to the right or to the left. The night-boats running on this river were masterpieces of work and engineering. What struck a stranger most was that they appeared to be without any officers. As a general thing, no one ever heard an order given. There were officers, but they could not be told from the passengers, as they were in citizens' dress. The boats were seldom stopped or slowed down from New York to Albany; but, when necessary, this

done by the pilot by the ringing of bells or of sounding gongs Mr. Evans.
ɪd in the engine-room, the pulls being within reach of the 's hand. The valves of the engines were poppet valves terbalanced, sometimes called compensation valves. The ıe-room was on the main deck, where passengers promenaded, ılways had the doors open ; it was generally without any one . The engineer, also in citizen's dress, was usually outside ıg the passengers; but near enough to reach the levers le the room in a moment, should the gong be sounded, and top the vessel before running much more than its own th. He had been familiar with the river many years, and more than once gone up and down it with the late Dr. lner, in 1841, who expressed his delight at the perfection of service.

e had an idea, that with double-engines, and anything but ppet-valves" in the engine, this happy handling of the boat l not be effected. All these boats had single engines, he never a boat with double-engines on the river, and it had always a mystery to him why the English would persist in having engines when one was sufficient; the two cost more, they pied more room than one, they required more care, attention, cleaning, they often worked to a certain extent one against ›ther, the risk of accident was in a measure proportioned to ıumber of pieces and parts in all, there was more waste and .ensation of steam in two cylinders than there was in one. ıt twenty-seven years ago he brought this matter of river s, and the use of one engine instead of two, to the attention of late Mr. Robert Napier, M. Inst. C.E., who said that the people ordered them would not have any other. He then attacked on the matter of short beam, long narrow deep vessels, instead ide sharp bows and flat bottoms. Mr. Napier answered, "The ›ricans are right, but the English will not have such vessels ou talk of. We know that every vessel that floats, no matter t her model, displaces her own weight exactly ; we know that y vessel afloat displaces her own weight in water every time runs her own length; we know that every vessel cuts a canal, ı the start to the stop, in the water equal in area and shape to greatest submerged midship section; and we know that it ıires more force to displace a cubic foot of water 20 feet below surface than it does at the surface, or any other depth less than eet." Mr. Napier admitted all these points, as he put them to in an inquiring way; he was induced to do so, as he had before made some voyages in four long narrow deep vessels

Evans. just sent out by him to the Pacific. From what he said Mr. Napier had evidently been trammeled in the models of those ships and of many more ships, by the owners, just as most of the English locomotive builders had always been trammeled by the engineers of the railways in England, who made drawings of every bolt and bar, lever and link, of every engine they ordered. It was astonishing to go among these steam-boat builders, and engine builders of America, and see how few of them were men of scientific education, and yet they worked out practically some of the most difficult problems to complete success in applied mechanics. Wiesbach could beat them in the constructive geometry and the algebra of the thing; but not a man could beat them in the practical application of an idea when once they comprehended it. This was mechanical instinct, just that happy faculty which George Stephenson possessed. More than thirty years ago Mr. J. Scott Russell, M. Inst. C.E., read a Paper before the British Association for the Advancement of Science on the "wave-lines" of ships, in which he demonstrated mathematically the propriety and value of such lines, and then said, "The Americans have been building ships on these lines for twenty years or more, but I doubt if there is a man among them that can demonstrate in figures the reason why they so build." He was right, at that time most probably there was not a single scientifically educated ship-builder in the United States, but times were changing fast.

He submitted data in reference to several American steamers. Of these, the "Drew" had been running as a night boat on the Hudson river, from New York to Albany, for about ten years. The "Rhode Island" ran as a night boat on Long Island Sound from New York to Fall river. This boat met the ocean wave after passing the eastern end of Long Island, and had been built to resist the greatest storms. The steam ferry-boat "Pacific," of the Union Ferry Company, ran from New York to Brooklyn across the East river. The steam ferry-boat "Plainfield," belonging to the New Jersey Central Railway Company, ran between New York and Jersey City across the North or Hudson river. The "J. M. White" ran on the Mississippi river from New Orleans to Grenville, 547 miles. He also presented some data in reference to the "Gitana," a steam yacht on the Lake of Geneva, belonging to the Baroness Rothschild. Finally he gave a list of ferries, and the number of ferry-boats running out of New York to New Jersey across the North river, and to Long Island across the East river.

Mr. Evans.

"DREW."

Length of vessel	380 feet.
Breadth ,,	48 ,,
,, ,, over wheel-boxes	75 ,,
Depth from main deck to keel	10⅓ ,,
Height from main deck to top of chimney	34 ,,
Diameter of paddle-wheels	40 ,
Length of face of floats	11½ ,,
Diameter of cylinder	6¾ ,,
Length of stroke	15 ,,
Pressure of steam generally used	45 lbs.
Greatest number of revolutions of wheels per minute	18
General speed per hour	18 miles.
Fuel burnt per hour	1½ ton.
Kind of fuel—anthracite coal.	
Number of passengers that can be berthed	1,000
Number of state rooms	200
Freight that can be carried all on deck	800 tons.
Draft of water, light	4 feet.
,, ,, loaded	6 ,,
Number of persons employed	75
Cost complete	450,000 dollars.
Kind of engine—beam.	

"RHODE ISLAND."

Length of vessel over all	340 feet.
Breadth of vessel	47 ,,
,, ,, over wheel-boxes	80 ,,
Depth of vessel from main deck to keel	15½ ,,
Height from main deck to top of dome	29 ,,
Height from hurricane deck to top of chimney	32 ,,
Diameter of wheels	39 ,,
Length of face of floats	11½ ,,
Diameter of cylinder	7½ ,,
Length of stroke	14 ,,
Pressure of steam generally used	25 lbs.
Highest pressure of steam ever used	27 ,,
Greatest number of revolutions of wheels per minute	19½
Greatest speed per hour	20 miles.
Average speed per hour	18 to 20 ,,
Fuel burnt per hour	2½ to 3 tons.
Kind of fuel—anthracite coal.	
Number of passengers that can be berthed	400
Number of state rooms	160
Greatest number of passengers carried	800
Freight that can be carried	500 tons.
Draft of water, light	9 feet.
,, ,, loaded	10 feet.
Number of persons employed	90
Number of cubic feet of gas burnt in a trip of 120 miles	1,800 to 2,000 feet.
Tonnage, Custom House measurement	2,740 tons.
Kind of engine—beam.	

Evans.

"PACIFIC."

Length of boat	185 feet.
Breadth „	30 „
„ „ over paddle-boxes	52 „
Depth „ main deck to keelson	12 „
Height of chimney „ to top	50 „
Diameter of paddle-wheels	22 „
Length of face of floats	7 „
Diameter of cylinders	3½ „
Length of stroke	10 „
Pressure of steam generally used	30 lbs.
Number of revolutions of wheels per minute	26
Kind of fuel burnt—anthracite coal.	
Kind of engine—beam.	
Fuel burnt in a day	7 tons.
Greatest number of passengers carried	1,000
Draft of water loaded	6 to 7 feet.
Number of men employed	5
Cost complete, about	80,000 dollars.
Age	20 years.

"PLAINFIELD."

Length of boat	225 feet.
Breadth „	30 „
„ „ over paddle-boxes	60 „
Depth „ main deck to keelson	12 „
Height of chimney „ top	48 „
Diameter of paddle-wheels	22 „
Length of face of floats	9 „
Diameter of cylinder	4½ „
Length of stroke	12 „
Kind of engine—beam.	
Pressure of steam generally used	25 to 30 lbs.
Number of revolutions of wheels per minute	30
Speed per hour	12 knots.
Kind of fuel burnt—anthracite coal.	
Fuel burnt in a day	7 to 8 tons.
Greatest number of passengers carried	3,000
Draft of water, loaded	6 feet.
Number of men employed	5
Cost complete about	125,000 dollars.

"J. M. WHITE."

Length of vessel	321 feet.
Breadth „ the hull	50 „
„ „ over all at rear guards	100 „
Depth from main deck to keel at centre	11½ „
„ „ „ „ at stem and stern	17½ „
Diameter of paddle-wheels	44 „
Length of face of floats	19 „
Depth „ „	3 „
Height of chimneys (two in number)	86 „
Diameter „	6½ „

"J. M. White"—*continued.*

Number of main engines	2	Mr. Evans.
Diameter of engine cylinders	$3\frac{7}{16}$ feet.	
Length of stroke	11 „	
Pressure of steam generally used per square inch . .	150 lbs.	
Pressure per square inch allowed by Government . .	173 „	
Pressure at which boilers are tested „ . .	259 „	
Kind of boilers—cylindrical: ten in number, of steel, 34 feet long, $3\frac{1}{2}$ feet in diameter, each with two 16-inch flues.		
Greatest number of revolutions of wheels per minute .	18	
General speed per hour against current	$12\frac{1}{2}$ miles.	
Current in river per hour	3 to $3\frac{1}{2}$ „	
Kind of fuel—wood.		
Number of state-rooms	126	
„ „ passengers that can be berthed in state-rooms	250	
Freight that can be carried	2,000 tons.	
Bales of cotton „	10,000	
Draft of water, light	$6\frac{1}{2}$ feet.	
„ „ loaded, about	9 „	
Horse-power (indicated) of both engines	4,000	
Main cabin or saloon, 233 feet long, 13 feet high, and 19 feet wide, exclusive of state-rooms.		
Journals of main shaft 21 inches in diameter; shaft and cranks of wrought iron.		
Each engine works one wheel independently.		
Engines of the horizontal-lever poppet class, with a connecting rod, 44 feet long.		
These engines, like all engines on the Mississippi river, are non-condensing. The vessel was built in 1877, and		
Cost complete	200,000 dollars.	

Ferries and Number of Boats.

Staten Island to North River.

Staten Island ferries (3 ferries)	6 boats.
North River, Barclay Street ferry	7 „
New Jersey Central railway, Liberty Street	6 „
Pennsylvania railway, Courtlandt Street to Desbrosses Street	7 „
Morris and Essex railway, Hoboken to 10th Street . . .	4 „
New York and Erie railway, Chamber Street to 23rd Street	8 „

East River.

Union Ferry Company	Hamilton Street, South „, Wall „, Fulton „, Catherine „	17 „
Williamsburg and Brooklyn Ferry Company . . .	South 7th Street, Grand „, Houston „	11 „
Greenpoint Ferry		2 „
Hunterspoint „		6 „
Astoria „		2 „
Total ferry-boats		76

Messrs. FLETCHER, HARRISON & Co., of the North River Iron Works, New York, supplied the following particulars of steamers constructed by them :—

———	"Mary Powell."[1]	"Chauncey Vibbard."	"Daniel Drew."	"Sylvan Dell."	"Sylvan Glen."
Boat.					
Length on water line, in feet .	286	281	265	178	153
" over all " .	295	294	277	185	160
Breadth of beam " .	34	34	33	26	26
" over guards " .	63	60	56	48	46
Depth of hold, top of floor-timbers to under side of deck, in feet	$9\frac{1}{2}$	$9\frac{8}{12}$	$9\frac{1}{2}$	$8\frac{2}{12}$	$8\frac{1}{2}$
Draft of water, from bottom of plank, in feet	$5\frac{8}{12}$	$5\frac{8}{12}$	$5\frac{8}{12}$	$4\frac{3}{4}$	$4\frac{1}{2}$
Engine.					
Diameter of cylinder, in inches	72	$62\frac{1}{2}$	68	51	40
Stroke of piston, in feet . .	12	12	10	8	8
Diameter of wheels, outside of buckets, in feet	$31\frac{8}{12}$	30	29	$25\frac{10}{12}$	$23\frac{1}{2}$
Face of wheels, length of buckets, in feet	$10\frac{1}{2}$	$9\frac{1}{2}$	9	8	7
Dip of buckets, in inches . .	42	39	39	31	27
Average pressure of steam, in lbs.	28	32	32	30	40
Cut off, part of stroke, steam follows full pressure . . .	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
Revolutions, at average . .	23	24	24	27	$26\frac{1}{2}$
Speed of boat, at average, in miles per hour	20	$19\frac{1}{2}$	$19\frac{1}{2}$	19	$17\frac{1}{4}$
Maximum pressure of steam, in lbs.	40	45	45	43	50
Maximum cut off, part of stroke, steam follows full pressure	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$
Maximum revolutions . . .	25	27	27	30	$29\frac{1}{2}$
" speed of boat, in miles per hour	22	22	22	$20\frac{1}{2}$	$18\frac{1}{2}$
Route.					
From New York to, and return	Rondout.	Albany.	Albany.	Harlem.	Harlem.
Miles one way	95	150	150	9	9
Landings one way	7	8	8	4	4
Average time, one way, including landings	5h. 25m.	9 hrs.	9 hrs.	39 min.	43 min.
Average time for all landings.	40 min.	40 min.	40 min.	12 "	12 "

The steamer "Mary Powell" was perhaps the best example of a fast river steamer in this part of the country, because the route

[1] *Vide* Journal of the Franklin Institute, 3rd Series, vol. lxxviii. p. 18.

ırsed was all in deep water, and with few landings for the Messrs.
:h of route. The business was also comparatively steady. Fletcher, Harrison & (
vessel carried passengers only (averaging about eight hundred) their baggage. The boat had for nineteen years done work ıe average stated in Table, with and against tide; during ptional runs, even greater speed than the maximum stated in Table had been obtained. The Albany day boats, "Chauncey ›ard" and "Daniel Drew," ran through the same water as the ıry Powell," and at times, in this deep water, make equally . runs; but 30 miles of their route below Albany was in shallow ır, which, in some stages of the tide, and in some places, was nuch more than enough to float the boat. The Harlem boats on the East and Harlem rivers, making one landing at Astoria ıe Long Island side. Their route was in swift flowing water, of eddies, and carried them through part of the notorious ll Gate." The speed given in the Table could, however, be y made by them in good water. These five boats were fair ıples of the best river boats. They were all built on the rican plan of saloons and passenger accommodation on and e the main deck. Only the dining-room, kitchens, and berths he crew, were placed below the main deck. They all had also American style of overhead beam engines with jet condensers.

R CHARLES HARTLEY stated that in November 1873 he in- Sir Charles Hartley.
ted the "City of Richmond" steamer at St. Louis, and obtained her captain the following particulars:—

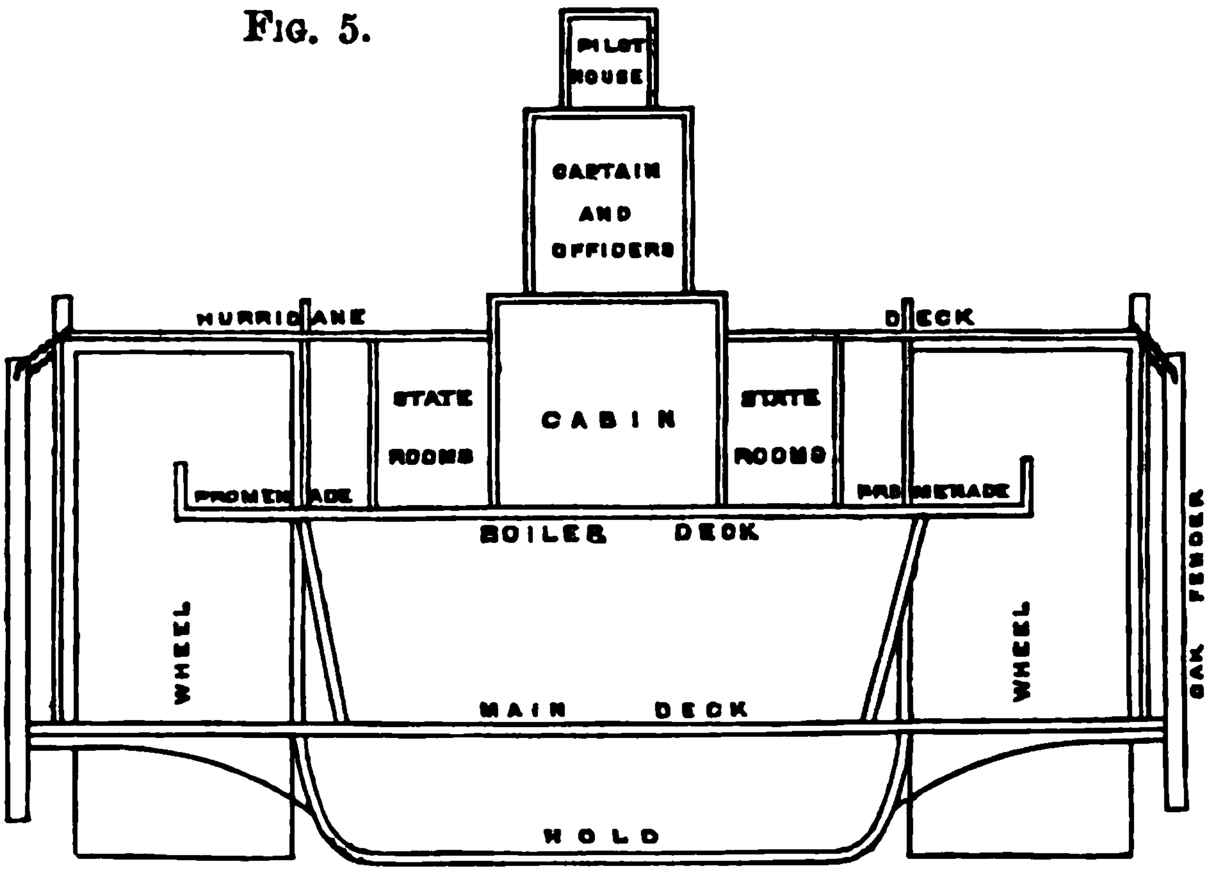
Extreme length of deck	340 feet.
" width "	85 "
Load line, draught	11 "
Light " "	4 "
Burthen	2,500 tons.
Freight carried	2,000 "
Cylinders, two, diameter	5 feet.
Length of stroke	10 "
Six boilers, pressure per square inch . . .	25 to 35 lbs.
Paddle-wheels, diameter	44 feet.
Floats "	14 "
Height from water-line to top of funnels . .	92 "
" " " pilot-house .	60 "

his steamer was then advertised as being the only low-pressure mer on the Mississippi river. She frequently accomplished voyage of 1,165 miles from New Orleans against a 2 to 3-knot ent in six days. She was built in 1867 for $232,000, and was three years afterwards to her present proprietors for $100,000. he following additional information regarding U.S. river

harles
ley.

steamers had been obligingly obtained for Sir Charles Hartley by Mr. Max E. Schmidt, of Memphis, Tenn., Member of the American Society of Civil Engineers, and chief assistant-engineer to Captain Eads, M. Inst. C.E., at the South Pass jetties during the whole period of their construction. The "Edward Richardson" was a side-wheel steamer, with wooden hull, of 2,048 tons burthen, extreme length, 313 feet; beam, 48½ feet; depth of hold, 10 feet; draught when light, 5 feet; draught when loaded, 12 feet; diameter of cylinders, 38 inches; length of stroke, 10 feet; boilers, nine in number, high pressure, 173 lbs. per square inch; diameter of paddle-wheels, 39 feet; length of paddles, 17½ feet; height from water to top of chimneys, 120 feet; to top of pilot-house, 75 feet;

Fig. 5.



Scale 30 feet = 1 inch.

SECTION OF THE "ED. RICHARDSON," MISSISSIPPI STEAMBOAT.

she was able to run at the rate of 15 miles an hour against a current of 3 miles an hour, when light; the steering was effected by hand, the wheel being about one-third of the distance from the stern of the boat; communication was effected between the pilot-house and engine-room by a speaking-trumpet and bells; the engines acted independently on each paddle-wheel, and thereby perfectly controlled the steerage; there were no bulkheads or watertight compartments; life-boats and life-preservers were carried sufficient for the passengers; the deck platform projected 21 feet on each side of the hull; the cabin on the boiler-deck was 240 feet long, 18 feet wide, and 16 feet high; there were fifty state-rooms, accommodation for two hundred and twenty-five first and second-class passengers, and when well filled with passengers,

8,000 bales of cotton in a non-compressed state could be carried with safety. Sir Charles Hartley.

In presenting this matter Mr. Schmidt stated that the steamers which navigated the Mississippi were chiefly transporters of freight, cotton being the main article. The passenger traffic, although by no means inferior in comfort, was only of secondary importance, and seldom paid large revenues to the owners. Certainly, two hundred and twenty-five passengers was a small number for so large a steamer as the "Ed. Richardson." But taking into consideration that the cotton was often piled up on both sides of the boat in four parallel rows of bales 40 feet high, the top reaching above the hurricane-deck, and thus completely hiding the exterior of the cabin, the importance of closely limiting the number of passengers became apparent. These steamers were often loaded down until the water flowed over the guards, but in such an event it was not attempted to run the boat up-stream. All freight went down the river, to the now open mouth, for trans-shipment to Europe. It should be stated that through the presence of cotton, and the imminent danger from fire, great precautions were enforced by law to prevent disaster. Hydrants and a full supply of hose were within immediate reach on all the decks. There was: 1, a main deck, on which the boilers, the engines, and the freight rested; 2, a boiler-deck, about 16 feet above the main deck, on which the cabin rested; and, 3, a hurricane-deck, about 17 feet higher, on which were officers' quarters, captain's state-room, and a pilot-house still higher. On the platforms or overhangs the cotton was piled. No better protection against the effects from collisions could be desired than this bulwark of cotton on each side, 21 feet in thickness.

Regarding the style of architecture employed in the construction of the Mississippi steamers, there was very little variety in shape, model and general appearance. The dimensions varied frequently, and alterations tending to the safety and comfort of the passengers, and to an economical disposition of freight, had been introduced with the progress of invention. The saloon or cabin was almost exclusively built upon the boiler-deck. The luxurious manner in which the cabin was finished on the larger steamers, and the perfection aimed at in all appointments tending to comfort were well known. Fig. 5 was a section of the "Ed. Richardson," which showed the position of the different parts of the steamer, and served in general to explain how the space on the larger Mississippi steamers was disposed. Ample room for promenade was obtained on the boiler-deck, each state-room having two doors,

Charles ...tley.

one leading into the cabin, and the other out on that part of the deck reserved for promenade. Perfect ventilation might thus be given to each state-room. Most of the promenade was covered by the hurricane-deck, or by tarpaulin to shelter promenaders from the heat of the sun or from rain. In order to protect the steamer from the wear and tear incident to landings, oak fenders, which on the "Edward Richardson" were 35 feet long, were suspended from the hurricane-deck to the water's edge. These fenders were placed at distances of 10 feet from centre to centre, and had given good results.

Mr. Schmidt had also supplied a pamphlet[1] descriptive of the U.S. mail steamer "J. M. White," in which was the following Table of the dimensions and power of the fastest steamers on the Mississippi river:—

Boats.	Built.	Hull.			Boilers.			Cylinders.		Paddle-wheels.	
Names.	Year.	Length.	Beam.	Hold.	No.	Length.	Diameter.	Diameter.	Stroke.	Diameter.	Floats.
		Feet.	Feet.	Feet.		Feet.	Inches.	Inches.	Feet.	Feet.	Feet.
Sultana	1843	250	35	8	7	32	42	30	10	[illegible]	14
J. M. White	1844	250	31	8½	7	32	42	30	10	32	15
Peytona	1846	260	35	8	6	32	42	30½	10	33	16
Aleck. Scott	1848	285	34	7¾	5	32	42	30½	10	..	..
Eclipse	1852	363	36	9	8	32½	42	36	11	41	15
A. L. Shotwell	1852	310	36	8	6	32	42	30	10	37	15
Princess	1855	280	38	9¼	6	34	42	34	9	40	..
R. E. Lee	1866	300	44	10	8	32	42	40	10	38	16½
Frank Pargoud	1868	250	41	9½	7	28	38	32½	9	36½	15½
Natchez	1869	301½	42½	9½	8	34	40	34	10	42	16
R. E. Lee	1876	315	48½	10½	9	32	42	40	10	[illegible]	17
John W. Cannon	1878	250	43	9½	7	[illegible]	42	34	9	37½	16
J. M. White	1878	321	50	11½	10	34	42	43	11	44	19

Kirk.

Mr. A. C. Kirk remarked that in constructing successful river steamers, whether the object was to build steamers which should carry passengers at the highest possible speed, or cargo on the least possible draught of water, the problem resolved itself into reducing the weight of hull, propelling machinery, and fuel.

[1] *Vide* "Description of the Steamer 'J. M. White,' Construction, Machinery, Outfit, &c." By Chas. H. Clarke, 8vo., Louisville, Kentucky, 1878.

the utmost. In putting the matter thus he assumed that the Mr. Kirk.
es and proportions of the hull had been made as good as circumnces would allow. In considering the three elements of weight, iich he had put above in order of their importance, it would be ivenient to invert this order and commence with the last.

1. *Fuel.*—The quantity of fuel to be carried would depend of irse on the quantity consumed per hour, and the frequency th which the coal bunkers could be replenished. The quantity be consumed per hour would depend on the machinery, and ould fall more fully under the next head. The frequency with iich the bunkers could be replenished depended on local conlerations. This to a great extent regulated the value to be tached to a low consumption of fuel, the longer the run before e bunkers were replenished, the greater the value of arrangements : economy of fuel.

2. *Machinery.*—In all except the very shortest runs, there was, questionably, a gain of speed to be got by using compound gines; the smaller quantity of coal to be carried being a decided ving; for the compound engine could be made with surface ndenser complete almost as light as any ordinary engine, and if orking in fresh water quite as light, the surface condenser being en dispensed with. For short runs and frequent coaling the ly question to be considered in determining whether a common compound engine be adopted was, first cost in favour of the mmon engine, and daily economy of fuel in favour of the comund. The most serious part of the weight was the boiler, and ich of the success of the Clyde steamers was due to the use of the ystack water-tube boiler, which not only occupied little space, t was light in itself and carried little water. The "Marquis of ite," a Clyde steamer, of 190 feet length, 18 feet breadth, with gines of 690 indicated HP., weighing, with the boilers and iter, 74 tons, was fitted with a single-cylinder injection connser engine, feathering wheels, and haystack boiler, the whole ight of machinery being 2·15 cwt. per indicated HP. as tried the measured mile at Wemyss Bay. As additional examples he ght mention "The Lancelot," of 190 feet length by 18 feet dth, having two oscillating cylinders and one haystack boiler. ie machinery and water weighed 60½ tons. The engines were of 0 indicated HP.; the whole weight of machinery being 1·76 rt. per indicated HP. "The Guinivere," 200 feet long by 19 et wide, having two oscillating cylinders and two haystack ilers. The machinery and water weighed 85·5 tons. The inicated HP. was 742, or 2·3 cwt. per indicated HP. "The Elaine"

Kirk. was 175 feet by 17 feet width. She had two oscillating cylinders and one haystack boiler. The machinery and water weighed 45 tons. The HP. was 420, 2·14 cwt. per indicated HP. There seemed little reason why for short-trip high-speed steamers forced blast should not be adopted, as had been done in torpedo boats.

3. *Hull.*—Little more in merely reducing scantlings could be attempted. Up to the present time but little change had taken place in the structural arrangement of river steamers, and years of experience and trial had pretty well settled the extent to which reduction of scantlings could be carried. In fact, the considerations of local strength imposed (except in the case of the largest) scantlings quite sufficient for general strength, and it was only in the largest of our river steamers that there was much room for improvement. In these, something might be done by applying the lattice principle, and the same strength got by increased depth as was obtained by shallow floors, &c., and beams of solid plate webs. But, unquestionably, the greatest improvement by which weight could be reduced had been the introduction of steel. By the use of this material not only could the required general strength be got with less thickness, but from the vastly greater margin for punishment and distortion before fracture occurs, a smaller margin of local strength would afford safety equal to that got with ordinary iron. At present, however, the real value of steel was but half got; ship-building authorities having ordained that ship steel should be as nearly as possible an imitation of wrought iron; as near to wrought iron in fact as the steel makers by taking the utmost pains could produce. The Liverpool underwriters had of late very wisely (though with even an excess of caution) been breaking through this prejudice. They had raised the limit of maximum strength from 30 tons, which had been adopted by the Admiralty and Lloyd's, to 32 tons, and he was happy to say they contemplated raising it to 35 tons, and there was no reason why it should not be higher. Up to 35 tons punching along with countersinking was quite safe; but why should the use of the punch limit the strength of the steel? With a proportionate reduction in thickness for increased strength it would pay every one concerned to drill, if that were found necessary. Steel must no longer be treated as if it were iron, and be made practically only iron. By a more intelligent treatment the higher qualities of the material should be utilised.

Lawrie. Mr. J. G. LAWRIE remarked that two classes of steamers had chiefly been considered in the discussion, "ferry passenger

steamers," and "ordinary river passenger steamers." In all steamers, whether river or sea-going, in which the speed desired was moderate, or not extreme, much greater scope existed for the development of strength than when the speed desired was extreme. By a small diminution of a moderate speed, greater strength might be obtained, or by increased length and breadth, and the accommodation afforded by the steamer would be unimpaired. But when the speed desired was extreme, or the utmost attainable, the elements of the problem were entirely altered. Take, for example, river passenger steamers, which were the steamers chiefly considered in the Paper itself, apart from the discussion, and practically, the problem to be solved was to produce a steamer which should combine in the greatest degree the requisite strength, with the requisite accommodation under and above deck, and the highest attainable speed. Under deck there was an after cabin, a fore cabin, a restaurant cabin, steward's accommodation, and other fittings. On the deck there was the deck saloon, with the promenade deck over it. The number of passengers for which the steamer was licensed was measured by the unencumbered deck surface. To reduce the deck surface was substantially to diminish the size of the steamer, and practically to make her of less length and breadth. To cripple, and therefore to lessen the under-deck accommodation by longitudinal or transverse bulkheads, or to transfer the under-deck accommodation to the deck, which would be the result of carrying out some of the suggestions proposed in the discussion, would be to reduce the gross amount of accommodation afforded by the steamer, and would therefore be to reduce the size of the steamer. If, in addition to this reduction of accommodation, fittings were introduced which would increase the weight of the steamer, the attainable speed would inevitably be diminished, and the efficiency of the steamer would be impaired. In the existing competition to produce the utmost attainable accommodation and speed, there existed the strongest inducement to use the best material, and the most effective machinery; and the inducement was equally strong to avoid the addition of weight, which involved a loss of speed or the reduction of accommodation. If Parliament ever rendered either course imperative, Parliament would simultaneously exact a diminished traffic, and consequently an increase of fares. For such a measure a stronger case of necessity must be made out than was at present possible. Accidents arising from the collision of steamers did, no doubt, happen occasionally, though very seldom, and they would continue to occur from time to time even though the strength were

Mr. Lawrie. increased. The true direction in which to look for safety was in the command of the steamer by steering, and in the facility of going ahead or astern. No suggestions made in the discussion pointed to improved and increased accommodation, or to increased speed beyond the results obtained in the modern Clyde river steamers, and he believed a careful consideration of the question would satisfy an experienced engineer that no such suggestions were possible. *A priori*, a broad gauge would seem to obtain for a train greater stability and greater safety than a narrow gauge, and probably it did do so; but experience had taught that in the accompanying evils the advantage was lost, and that the narrow gauge was the best for the purpose. Similarly an increase of bulkheads and increased strength in a river passenger steamer were apparent advantages, but experience proved that they were better omitted.

Mr. Mackie. Mr. S. J. Mackie said it was familiar to every engineer, that in no other way could any given weight of iron be disposed to such advantage as on the tubular bridge or "box-girder" form. By applying this principle to the designing of ships, the strongest construction of hull was obtained with the utmost amount of security; and, as in the application of all right principles, every subsequent requirement entered into harmony with the main outlines. A central tubular chamber could be thus produced perfectly watertight and totally independent of the external hull or outward form of the ship. By this means the effect of any collision on the broadside would be limited to that particular small section or exterior cell alone which was breached by the blow; for what would have been a single large compartment of the vessel under the existing ordinary division by transverse bulkheads, would, by the introduction of two longitudinal girders, be subdivided into three portions, of which the middle one would always remain intact if either or both of the external spaces were destroyed. The division of the hull by two longitudinal girders would suffice to give ample security; but the safety of the vessel would be still farther advanced if the saloon above deck constituted a portion also of the interior tubular chamber, by making its walls to form the upper parts of the longitudinal girders, and thus increasing their depth. In the earlier designs of vessels upon this plan, a novel mode of hydraulic propulsion was introduced, to allow of which the beam of the vessel was increased by a second set of longitudinal girders, with an interspace for the flood of water by which the propulsion of the ship was effected. At the same early period, however, the idea was also developed of making

or converting ordinary vessels into safety ships, by the introduction Mr. Mack of two longitudinal girders, whereby a central tubular chamber was practically formed, by which the security of both vessel and cargo was ensured. He exhibited a model, an illustration of a sea-going vessel of this safety class, designed by Mr. George Hollingum, a naval architect, in consultation with himself, for the service of the South-Eastern railway, between Folkestone and Boulogne. The dimensions of this vessel were the largest that Company's harbour at Folkestone in its present state would admit, viz., length, 250 feet; breadth of hull, 30 feet; extreme breadth from outside to outside of paddle-boxes, 50 feet; load draught with five hundred passengers and 80 tons of cargo and coals, 8 feet; engine power, 2,500 HP. indicated; and estimated speed 18·37 knots per hour. The saloon formed an integral part of the ship, contributing enormously to its strength and rigidity. On the other hand, the saloons of ordinary vessels were mere deck-houses, adding further burthens to long beams and slender scantlings, already suffering under severe stresses from ever present and ever varying contortional strains. The iron walls of the saloon were continued down to the double bottom formed by the base of the central box-girder chamber; an iron deck constituted the floor of the saloon, and nearly all the space below this was devoted to the engine power and to the service of the ship. The top of the saloon afforded a promenade, which, from its height above the sea, would be available in almost any weather, and in summer would give accommodation to a considerable addition to the five hundred passengers which were regarded as the ordinary freight. The motive power was disposed in three distinct sections of the middle division, of which the engines themselves occupied the central one, the boilers being respectively placed in the forward and after ones. By this arrangement the whole of the middle body of the saloon was preserved for the best accommodation of first-class passengers. It was naturally the part of least motion in the entire vessel—a consideration of the very highest value for the comfort of the passengers. By this disposition of the motive power, other and very important advantages were attained. Thus, in the case of collision, if even the inner girder of the central tubular chamber should be pierced, which was not likely, and one of the boiler compartments were thus to be filled with water, the other boiler compartment would remain intact, and the engines would be supplied with steam to the extent at least of half-boiler power. As to the engines themselves, protected as their compartment was, not only by the double iron wall of inner longitudinal

Mackie. girder and outer skin, but further defended by the projecting paddle-boxes and sponsons, it was not easy to believe they could receive, in even the most extreme degree of violence in collision, any disabling damage; and if they were, as according to his own views they should be, independently fitted to each paddle-wheel, their complete derangement would be next to impossible. Under the existing arrangements of ordinary ships, where the boilers and engines were in the closest proximity, considerable inconvenience from heat would be experienced in that part of the saloon disposed over them; but in the present plan the heat from the boilers was minimised by the distance at which one half the furnaces were placed from the other half of the furnaces, whilst very little heat indeed was given off from the cylinders of the engines themselves; so that, in the present instance, any slight increase of temperature from these causes was kept so low as to be of no practical consequence. The steam was conveyed in covered pipes in the cellular spaces between the outer skin and the inner longitudinal girder on each side of the engine-room, and consequently no inconvenience arose from this source. The construction of the saloon, moreover, allowed of perfect ventilation, and was such as under ordinary circumstances would provide against any discomforts from overheated atmosphere. In the case of grounding, the double bottom of the safety vessel would form an effective protection; and in such circumstances as running on a rock at full speed, and remaining on the fall of the tide, with such long overhangs that the weight of the cargo would inevitably break an ordinary vessel in twain, the longitudinal girders of the central box-girder chamber would be equal to the strains, and everything would remain as secure in the ship as the goods or passengers in a train passing through the Menai or the Conway bridge. The final subject for notice in the description of the model vessel was her speed, for engines of such power could not be worked at such extraordinary rates of revolutions in any ordinary light-draught vessel without ceaseless and serious depreciations of the hull, through the irresistible vibrations propagated through its ill-constructed fabric, whilst the engines themselves were liable constantly to injury from heated bearings and other evils of contortional strains. The rigidity of the box-girder central chamber, the shortness of all bearings in consequence of its construction, and the supports which the longitudinal girders gave to the paddle-shafting and to the framings of the cylinders, were such, that vibration would be prevented by the smoothness with which the vessels would run under such advantageous conditions, to say

nothing of the disposition of the materials of the safety-hull for Mr. Mackie. encountering such vibrations if they could arise. It might here be incidentally remarked that such a speed as over 18 knots per hour was not conceived by previous designers for steamers of such limited dimensions, and adapted for that particular service. It was as unnecessary as it would be out of place to dwell at greater length upon sea-going vessels, and the example brought forward was only introduced because it was clear that, with obvious modifications, it would be as much the type of a true river-steamer as in its actual form it was an effective type of ship for channel passage. Whatever in its fundamental principles was important in regard to strength and security, was not less but more important in vessels adapted for river services, where the freights carried were almost always and entirely passengers, and in regard to which security to life ought to be alike the primary foundation of the principles of construction, and the ground of official certificate for plying with passengers. To begin in such onerous services with utterly insecure hulls, and to trust to life-buoys and floating-seats in a first as well as last emergency was radically wrong. The fundamental object in the design of such steamers ought to be the preservation at all times of sufficient buoyancy in the hull itself to secure its flotation under even extreme conditions. This was most certainly to be relied upon by having the reserved buoyancy spaces devoted to that purpose specially, and not to be used for anything else whatever. One could not say this could only be done by the double-skin system of construction, of which the model was an example; but one might say that under no other than similar circumstances would the reserved spaces be likely to be kept in a condition of reliability in sudden emergencies. The inter-cellular system between the longitudinal girders and the outer skin was one which caused the least inconvenience in the arrangement of the internal capacity of the hull; and two light-class steamers for river and canal traffic which were designed in 1870–1, were examples of how much could be made and done upon the central tubular-chamber system for the real accommodation of travellers. Both these vessels, the one intended for the Thames stations and the other for one of the Austrian canals, were adapted to the system of hydraulic propulsion, at that time proposed, and which it was still considered would be the best suited for river or canal purposes. It would be clear, however, that if the hydraulic propulsion were put aside for the ordinary paddle or screw, that vessels could be produced far more efficient and incomparably safer than either of those employed at the

Mackie. present time on the Thames or the Clyde. For river work, where there was putting alongside of quays or piers every few minutes, and where excessive speed was not an object, and ordinary speeds of 10 or 12 miles an hour the utmost working speed attained, the hydraulic propulsion would give the advantage of an unobstructed ship side, and this condition had also been availed for giving greater facilities of ingress or egress for passengers by means of landings specially formed by the turn-over of the bulwarks. Another advantage of the hydraulic system was its capacity for the rapid handling of the vessel. By it all degrees of turning-power were available, up to actually pivoting the ship by turning one current ahead, and the other current astern. The saloon need not be entirely above deck, but might be partially seated in the hull proper, so as to leave a portion only of its elevation exposed above the deck-line. The subdivisions of the boilers and engine would have a very high value in such river vessels as were of sufficient dimensions to permit its adoption; and there were very few, if any, in which protection by longitudinal girders could not be adopted. The subdivision of the motive power ought to be insisted on authoritatively in all the larger passenger vessels, particularly those employed for excursions, such as the saloon boats of the Thames or Clyde, where from five hundred to one thousand or more passengers were carried on holiday excursions. No door openings were permitted in the sides of the saloon; the passengers should all enter the saloon from above, or at least from a break of some height above the deck proper. By this means a space of deck was left all round for the proper working of the ship by the crew; and the raised portion of the saloon always thus remained as a combing to keep out the water from the central tubular chamber, even if the deck proper were actually submerged, or a part of it immersed. He might be pardoned for asking the mental comparison of a vessel so constructed with the common sight of one of the Thames saloon-boats in the summer, with scores of hands out of the ports waving handkerchiefs, or dipping them in the waves of the currents from the paddles, the whole vessel swaying from side to side with the motion of its living freight, any sudden rush of which, in any impulse, might bring in the flood through those fatal windows, at best only a foot or two above the level of the steamer's draught. In river-boats, the imperforate character of the ship's side, and of the longitudinal girders, were the most important elements of safety, and any opening in either ought never to be permitted. In conclusion, he would only add that the imperforate condition of the longitudinal

girders in sea-going vessels was not only of value in protecting the ship from the dangers of leakage and sinking, but the triple division of the hulls of cargo vessels had the further advantage of preventing those shiftings of cargo in stormy weather which so often led to the abandonment, or not unfrequently the total loss, of the ship. Mr. Mackie.

Captain Pim

Captain BEDFORD PIM, R.N., M.P., stated that he knew the Thames, the Mersey, the Clyde, and the nature of the passenger steamers plying upon those rivers. He knew something also of the river steamers of Europe, Asia, Africa, and America, and he had no hesitation in saying that the English people had the worst service of river passenger traffic in the world. That on the Mersey was the best in Great Britain, because it was an imitation of the American system. It would be amusing, if it were not humiliating, to hear the comments of Americans on the Thames passenger steamers, of which they expressed their disgust in no measured terms; in fact, there was only one redeeming feature about the service, and that was the great skill with which the vessels were handled by the Watermen and Lightermen of the river, who fortunately for the public must be employed to navigate the steamers; every exertion ought to be made to encourage so useful and trustworthy a body of men. It was not too much to say that if one of her own crew had been at the wheel of the "Princess Alice" instead of a stranger, the collision between that vessel and the "Bywell Castle" might have been avoided. Several points in the Paper cropped up which should be explained; for instance, speaking of the vessels on the Thames above bridge the Author said that under the circumstances of dealing with the traffic of a restricted and crowded smooth water area, "great strength of hull would defeat its object." The Author would perhaps be surprised to hear that the above-bridge boats were stronger than those below. First, because they were not out of all proportion too long for their beam, and secondly, because strength was specially secured by the simple expedient of placing a timber stringer fore and aft on each side of the vessel below the deck, so that another craft running into her would have to cut through this stringer, which he thought was (for he feared the new boats were not built in this way) 12 inches wide by 6 inches thick, before knocking a hole through the skin. The Author also pointed out that "high speeds and large carrying power lead to the employment of long vessels." But Captain Bedford Pim considered the employment of long vessels a great mistake, not to say a blunder.

ptain Pim. Compare the "Princess Alice," for example, with a Hudson river boat. The former was 220 feet long by 20 feet wide, and 7 feet deep; in other words, eleven times her beam for length, and thirty times her depth for length, the extreme breadth between the paddle-boxes being 37 feet. It was hard to speak of such a vessel with patience. She was a mere gas-pipe cut off to measure and sharpened at both ends. The exact shape might be made clear to any reader of a penny newspaper; if he would cut a column of that paper and add one sixth to it, he would find it eleven times the breadth to the length, the proportions of the "Princess Alice," and of other river boats also. It must be apparent to everybody that a slight blow struck near amidships was quite sufficient to destroy such a craft. The force of the blow of the "Bywell Castle" had been described as a mere kiss; but, nevertheless, the "Princess Alice" actually parted in halves immediately, and so completely that the foremost half turned round and headed down stream before it sank. In fact, directly a ship was lengthened, the risks increased, and the vessel became more unseaworthy. It was astonishing that long vessels of the "Princess Alice" type were allowed to run on the Thames below bridge, where the traffic was not, as the Author stated, "end on," as was proved by the collisions taking place in nine cases out of ten before or even abaft the beam. He believed that if the Board of Trade did their duty, and strictly enforced the law laid down in the Merchant Shipping Act of 1854, which enacted that two surveyors, a shipwright surveyor as well as an engineer surveyor, must certify to the fitness of the steamer for service, there would be a decided falling off in shipping disasters. The last return (1877–8), for instance, showed wrecks, casualties, and collisions in or near the coasts of the United Kingdom, amounting to three thousand six hundred and forty-one, or nearly ten a day, with, of course, the usual proportion of lives lost. In fact, the state of the Mercantile Marine and the passenger steamers of our rivers was disgraceful. When he reflected on the difference between our river passenger steamers and those of the United States, he was surprised that the English public were content with such wretched accommodation. He knew of no American river boat more than six times its beam for length at the outside; generally it was five, and even that was below the overhang. It could, therefore, readily be understood how much more handy American vessels were than vessels of the "Princess Alice" type, of eleven times their beam, to say nothing of their great additional safety and buoyancy. But the most important feature, so far as safety was concerned, lay in the overhang, or strong deck, extending

several feet beyond the hull, and which, in the event of a collision, Captain
acted as a fender. The characteristics of the river passenger steamers in American waters were great speed, handiness, comfort, stability, buoyancy, and seaworthiness, and great strength and durability, in all of which attributes English vessels were lamentably deficient. To give an idea of the speed and comfort of these vessels, he might mention one or two instances. He made a passage in the old "Constitution," from Newport, Rhode Island, in winter, up Long Island Sound to New York, the first part of the voyage exposed to the full roll of the Atlantic waves. There were nearly one thousand passengers on board; the ship drew 9 feet of water, and travelled easily at the rate of 17 miles an hour. There were sleeping berths for all, from a splendid cabin lit by gas, and with hot and cold water laid on, to the common bunks for emigrants. The main saloon was covered with Brussels carpet; and easy chairs, not secured to the deck, thus showing the smooth motion of the ship, invited in every direction the passengers to be seated. In these chairs many passengers slept to save the cost of a cabin. He afterwards went up the Hudson in a similar vessel, but at an average speed of nearly 18 miles an hour the best part of the way from New York to Albany. With regard to strength he had a most unpleasant opportunity of testing that point. Coming up from Grey Town, Nicaragua, in the "Santiago de Cuba," the steamer ran on shore northward of Cape Hatteras, with a nasty sea on, and unfortunately several of the passengers were lost in trying to land through the surf. The ship, however, held together, and when the weather moderated she was got off with but little damage to the wooden hull. He thought he had said enough to show the immense superiority of the American river boats over English boats. He hoped the Institution of Civil Engineers would be the means of directing attention to the fact, that long narrow vessels were not adapted for either sea or river traffic, for they could not answer the helm as quickly as necessary, they had little inherent stability, comparatively poor accommodation, and were certainly not faster than the beamy American boats, while, beyond question, they were more risky. He might mention that the hull of long vessels actually cost more than the hull of short ones, and this could be proved by the following method: A and B were vessels of the same tonnage, the cubic contents being 972 each; A had a length of 270 feet, beam 30 feet, depth 30 feet, and all round measurement of 540 feet. B had a length of 180 feet, beam 45 feet, depth 30 feet, and all round measurement of 360 feet. Now it would be seen that the

n Pim. long narrow ship, with the same depth of hold as the broad one had, was nevertheless 180 feet more in circumference, and therefore cost so much more for materials and workmanship, to say nothing of increased friction. Moreover, the strain, the wear and tear, and the consequent additional outlay for repairs, putting on one side the extreme uneasiness of these long vessels, was surely sufficient to condemn them. He was at a loss to understand why such a form was still adhered to, particularly when, as was now proved, the natural shape of ships was in every respect so far preferable. In conclusion, he wished to point out that no matter how great the skill of the naval architect, how conscientious the workmanship of the builder, or how scientifically strengthened the vessel might be, all was of no avail without men to navigate it, brave, ever watchful, well trained, such as were happily found in the Watermen and Lightermen of the River Thames.

obinson. Mr. W. C. Robinson remarked that the through passenger traffic on the River Rhine from Mannheim to Rotterdam was in the hands of two companies, the Cologne-Dusseldorf Steam Co., and the Netherlands Steam Co. The boats of the latter company ran a mixed goods and passenger traffic; whereas the former company had in its hands the bulk of the great summer passenger traffic on that part of the river which offered most interest in its scenery between Bonn and Mainz. There was nothing particularly worthy of notice in the ordinary steamers of either company; they were almost without exception constructed on an old-fashioned, but practical paddle-steamer model, imported from the Thames in the year 1839, and which had not been materially departed from since. They had generally three bulkheads, but no great attention was paid to watertight compartments, the river being nowhere very deep, and the risk of sinking therefore hardly worthy of consideration. The engines were, as a rule, low pressure, not compounded; the price of coal being moderate, as the river skirted the great Westphalian coal basin, the passenger steamship companies had not yet adopted the newer system, whereas the tugs and cargo steamers had nearly universally done so. The last steamer from England was imported in 1845, since which time both companies had constructed their boats in Holland, the Cologne-Dusseldorf Co. at the wharf of Mr. L. Smit, at the Kinderdijk, a well-known and successful builder of iron steamers; and the Netherlands Co. at their own wharf at Fyenoord, near Rotterdam. In the year 1869–70 the Cologne-Dusseldorf Co. constructed four saloon passenger boats on the most approved model, under the in-

spection of their technical manager, Mr. Dietze, through whose kindness he was able to supply a diagram (Plate 8) of these steamers. They had proved very successful. They could carry one thousand passengers each, and had more than once transported a whole infantry battalion (one thousand men) with all effects, &c.; they could comfortably accommodate six hundred passengers, with luggage, and could dine one hundred and seventy-five persons in their excellently arranged deck saloon, whose large and high windows permitted an uninterrupted view of the scenery on both sides. These boats had also three compartments, and had no special safety arrangements in case of collision; but the risk was a minimum one. They ran from Mainz to Cologne. The following were the particulars of construction, speed, &c.: Length, 260 feet; breadth, 24 feet; draught, 3¼ feet; displacement, 355 tons; HP., 140 nominal, and 900 indicated; revolutions, 43 per minute; the engines were low pressure, by Ravenhill, Salkeld & Co.; the cylinders 46 inches in diameter, and the length of stroke 4 feet; the coal consumption was 3,248 lbs. per hour, or 3·6 lbs. per indicated HP.; the maximum steam pressure was 30 lbs. per square inch, and the vessel attained a speed of 13½ knots per hour. Mr. Robin

There were numerous small local passenger steamers on the upper and middle Rhine, generally, however, of an antiquated model and of inferior construction, cheapness being in all these cases too much a desideratum in Germany. Nor did the Dutch passenger steamers, plying from Rotterdam to the interior of Holland, offer much to remark upon. They were, as a rule, much better constructed than the German boats of the same class; cattle and goods traffic were combined with passenger accommodation of a very modest description. The paddle steamers plying between Rotterdam, Dordrecht, Gorinchem, Bois-le-Duc, Middleburg, Brielle, &c., were generally old boats of a type of hull used thirty years ago in England. Lately, however, a few steamers of improved model had been introduced on the more frequented passenger routes. For canal navigation small screw steamers were employed in great number. The bulk of the ferry steamers on the Rhine were small, old, and of obsolete construction. The Rhenish Railway Co. had constructed at Griethausen, near Cleve, and at Bonn, steam ferry-pontoons which took a whole train across the stream at once, by an engine hauling on a wire rope stretched across the bed of the river.

Mr. David Rowan observed that one danger to river steamers which had not been referred to, but which might be peculiar to the Mr. Rowa

Cowan. Clyde, was that in that river there were many timber ponds, especially about Port Glasgow. These were not well protected, and in stormy weather the logs not unfrequently got adrift. The Clyde Trustees exercised considerable vigilance in looking after and picking these up. He had known upwards of one hundred of them collected at one time, floating about and lying on the banks within the jurisdiction of the Trust. When these logs were hard wood floating all but submerged they were not easily seen, and if any of the river steamers when at full speed were to strike one in the right place and the log in the proper direction, no doubt it would break the plate and cause disaster.

Sharrock. Mr. S. SHARROCK offered the following remarks on the ground of actual long experience in the designing and constructing of many light and shallow draught vessels for Indian and other foreign rivers. In his opinion the chief and most essential structural conditions to be secured in these vessels were the following:—

1st. Such vessels being necessarily very light, a far higher quality of iron should be insisted upon in their construction than was usual for sea-going vessels.

2nd. More numerous and really watertight bulkheads than was customary in river steamers were essential, both transversely and longitudinally. Whilst these bulkheads, so far as the plating was concerned, must be light, yet they should have sufficient lateral stiffness, by ribs or frames, as to be able to resist any possible maximum head of water without collapsing or bulging in.

3rd. Owing to their frequent small depth in proportion to length, special attention was needed to secure strength at the deck level, in order to permanently resist the stresses occasioned by an unequal or severe local loading by machinery, passengers, water in compartments, or grounding in shallow rivers or on the banks, and much more strength than was customary was needed at the waterway plates or deck stringers to resist either tension or compression.

4th. The riveting of these light vessels should be of a special character, viz., the longitudinal seams of skin plating should be double riveted, and the butt ends of plates should be treble riveted.

With regard to the principle upon which the number of watertight compartments should be determined, he was fully of opinion that they should be of such number as would enable the vessel to carry her load safely with any one of her compartments completely

broken into by collision. No doubt the owners of such craft must be required to provide able and experienced commanders, careful, and with the fertility of resource derived from long experience. Yet he was convinced the above structural conditions were quite as essential, and quite as necessary to avoid loss of life. Mr. Sharr

Mr. J. EVELYN WILLIAMS agreed with the Author as to the points of importance to be studied in designing river passenger steamers. He would, however, like to add another point, viz., that in all cases where the cabin was situated below deck, ample and easy means of exit should be provided in case of emergency. In some river passenger steamers the cabin was a long triangular cavern below deck at the extreme end of the vessel, and from which the deck was only gained by a fixed step-ladder or straight narrow stairs. In the event of collision the loss of life for want of proper and easy means of exit from these cabins might be serious. Mr. Willia

The hulls of all river passenger steamers should be subdivided into a series of compartments by perfectly watertight bulkheads, the distance between any two adjacent bulkheads should be so regulated that the vessel would float safely were any one of the compartments to be filled with water, or be placed in free communication with the sea. In cross-river traffic the main deck of the vessel should be carried out on each side so as to form a continuous fender or sponson to protect the hull proper in the event of collision. In designing vessels for such traffic, buoyancy and staunchness should be more important elements of consideration than high speed and luxurious saloons.

In cross-river traffic, such as that on the Mersey, exterior means should also be adopted for further protecting human life, and to minimise the risks of collision on rapid tidal streams; for example, the principal ferry track across stream should be defined laterally by means of a floating beacon anchored in mid-stream on each margin of the track. These beacons should exhibit an electric light at night, and sound a powerful horn or bell during fogs. Within the limits of the ferry track so defined, steamers going up or down stream should proceed with extra caution and slackened speed, and be strictly prohibited from anchoring there. Thus a clear and defined ferry track would be secured, and the risks attending cross-river traffic would be considerably diminished. Further, in the case of all river passenger traffic, clear and definite steering signals should be understood, so that in the event of vessels approaching each other, the steam whistle sounded, say twice, should mean "I port," or "I starboard," as the case

Williams. might be; the intended course of the approaching vessels would thus be definitely known, and the uncertainty and confusion which so often resulted in collision and loss of life would be avoided.

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9 and 16 December, 1879.

WILLIAM HENRY BARLOW, F.R.S., Vice-President, in the Chair.

The discussion upon Mr. Carson's Paper, on "Passenger River Steamers," occupied both evenings.

ANNUAL GENERAL MEETING.

23 December, 1879.

JOHN FREDERIC BATEMAN, F.R.SS. L. & E., President, in the Chair.

The notice convening the meeting having been read,

Messrs. A. T. Atchison, J. D. Baldry, R. W. P. Birch, C. Frewer, C. E. Hollingsworth, H. Law, R. C. May, T. M. Smith, J. Thomson, and A. Williams were requested to act as Scrutineers of the Ballot for the election of the President, Vice-Presidents, and other Members of Council for the ensuing year; and it was resolved that the Ballot Papers should be sent for examination at intervals during the time the Ballot remained open.

The Ballot having been declared open, the Secretary read the Annual Report of the Council, on the Proceedings of the Institution during the past year. (*Vide* page 187.)

Resolved,—That the Report of the Council be received and approved, and that it be printed in the "Minutes of Proceedings" in the usual manner.

The Telford and Watt Medals, the Telford and Manby Premiums, and the Miller Prizes, which had been awarded, were presented. (*Vide* pages 200 and 201.)

Resolved,—That the thanks of the Institution are justly due and are presented to the Vice-Presidents and other Members of the Council, for their co-operation with the President, their constant attendance at the Meetings, and their zeal on behalf of the Institution.

Mr. Barlow, Vice-President, returned thanks.

Resolved unanimously,—That the cordial thanks of the Meeting be given to Mr. Bateman, President, for his persevering endeavours in the interests of the Institution, for his unremitting attention to the duties of his office, and for the urbanity he has at all times displayed in the Chair.

Mr. Bateman, President, returned thanks.

Resolved,—That the thanks of the Institution are due, and are presented to Messrs. Alfred Rumball and W. B. Lewis for the comprehensive statement of Receipts and Payments they have pre-

pared; and that Messrs. W. B. Lewis and Charles Douglas Fox be requested to act as Auditors for the ensuing year.

Mr. W. B. Lewis returned thanks.

The Scrutineers then announced that the following gentlemen had been duly elected:

President.

WILLIAM HENRY BARLOW, F.R.S.

Vice-Presidents.

James Abernethy, F.R.S.E.
Sir W. G. Armstrong, C.B., F.R.S.
Sir Joseph Wm. Bazalgette, C.B.
James Brunlees, F.R.S.E.

Other Members of Council.

George Berkley.
Fred. Jos. Bramwell, F.R.S.
George Barclay Bruce.
Sir John Coode.
Edward Alfred Cowper.
Alfred Giles, M.P.
Sir Charles A. Hartley, F.R.S.E.
Harrison Hayter.
William Pole, F.R.SS. L. & E.
Robert Rawlinson, C.B.
Charles William Siemens, F.R.S.
David Stevenson, F.R.S.E.
Sir W. Thomson, F.R.SS. L. & E.
Sir Jos. Whitworth, Bart., F.R.S.
Edward Woods.

Resolved,—That the thanks of the Meeting be given to Messrs. Atchison, Baldry, Birch, Frewer, Hollingsworth, Law, May, Smith, Thomson, and Williams, the Scrutineers, for the promptitude and efficiency with which they have performed the duties of their office; and that the Ballot Papers be destroyed.

ANNUAL REPORT.

Among the many subjects of interest to the members of the Institution, there is no more important one than the consideration whether the objects of the Society—as contemplated by the eminent men who founded it, and for which it was incorporated by Royal Charter—have been adequately fulfilled; and if not, then in what way they can hereafter be more properly carried out. The Institution was established in 1818 "for facilitating the acquirement of professional knowledge, and for promoting mechanical philosophy." In the Charter of 1828 the Society was stated to be "for the general advancement of Mechanical Science, and more particularly for promoting the acquisition of that species of knowledge which constitutes the profession of a Civil Engineer;" and then followed an abstract of Tredgold's description of the works of those days embraced within the profession.

Very soon after the foundation of the Institution periodical meetings for the reading of Papers and for the discussion of engineering topics were held, but no publication of the Papers was made until the year 1836. Then, following the example of an older Society, a selected number of the Original Communications received up to that time were embodied in a quarto volume of "Transactions." This volume contained, however, no record of the discussions to which the Papers gave rise. In course of time it was found that the Transactions—which only reached three volumes—were so expensive as to be beyond the means of the Institution at that date; and moreover, that they did not fairly represent the work of the Society, or of its members, at the weekly meetings. It was then determined that the principle of selection should be abandoned, and that the whole of the Papers, together with an abstract of the discussions upon them, should be given in the "Minutes of Proceedings." This series of publications had been commenced in 1837, almost concurrently with the Transactions; but the Papers and the discussions were so briefly recorded that the Proceedings for that session only occupied 47 pages. By the year 1845, however, the Proceedings were enlarged to 410 pages, and were illustrated by 29 plates, besides woodcuts. Gradually the matter increased, so that in the session 1869–70 it was thought advisable to divide the Proceedings into two volumes, each averaging 450 pages—a plan that was followed up to the session 1874–75. Then, owing to the progress of the Society, and to the

fact that many of its members were resident in distant countries, where access to current engineering literature was difficult, the Council recommended a further enlargement of the publications, so as to embrace Original Communications other than those read at the meetings, and also Abstracts of Memoirs either addressed to similar bodies abroad, or printed in foreign scientific or technical periodicals. Thus was arrived at the present system of issuing four volumes annually—a system which has prevailed for five years. During the past session these volumes—issued respectively in the months of March, May, July, and September—have together contained 1,704 pages. The Minutes of Proceedings proper, including the Papers read at the meetings, reports of the discussions upon them, and written remarks, embrace 885 pages, the Other Selected Papers occupy 343 pages, the Obituary Notices of deceased members 80 pages, and the Abstracts of Memoirs contributed to Foreign Societies and Periodicals 396 pages. Every member, whether belonging to or only attached to the Institution, and wherever resident, receives, post free, a copy of each volume as published.

It must be admitted that the meetings themselves tend very materially to the advancement of scientific knowledge in its application to engineering, by promoting the interchange of opinion among the best authorities on the subjects introduced. At the same time the complete and rapid circulation given to the records of such meetings, supplemented as it now is by the additions before described, furnishes perhaps the most efficient plan that can be devised for the collection and dissemination of information on all those many sciences upon which the successful practice of engineering depends, throughout all those places where the members are to be found. It is obvious, however, that this plan depends, for its full success, upon the readiness with which the members contribute, in some shape or form, to the "Minutes of Proceedings." It rests with them to present Original Communications, to take part in the discussions at the weekly meetings, and to furnish the particulars of engineering works at home, as also to make known useful facts and deductions acquired in the course of practice and observation. These desiderata have been repeatedly urged upon the consideration of all within the Institution; but they have lately acquired additional force, inasmuch as it is impossible to avoid being struck by the fact that, although the Foreign Abstracts furnish information as to engineering works in all parts of the world, no similar particulars are to be found in the "Minutes of Proceedings" respecting such enterprises at home, unless any work be of sufficient importance to form the subject of

a separate Paper. The Council therefore reiterate that they are most anxious the members should avail themselves of the opportunity of recording in the "Minutes of Proceedings" any particulars of interest to the profession, *e.g.*, the cost of different viaducts and tunnels on a line of railway, the mode of driving headings and of sinking foundations, the efficiency of different systems of rock-boring apparatus, the mode of transport of heavy materials in hilly countries, impromptu contrivances for dealing with unforeseen difficulties or for averting accidents, and a vast variety of other data which will suggest themselves to every practical engineer. The Council may point to the Selected Papers and to the Foreign Abstracts in recent volumes as examples of the great variety of information on matters of detail that might be saved for the profession—information which is at present but too often put away and forgotten after the matter to which it relates has been accomplished. The publications of the Institution ought virtually to constitute a current history of engineering, and it should be a subject of personal concern to every member that this history should be as complete as possible.

The next means that may be pointed to for promoting the objects of the Institution is the Library. It is in evidence that in the early days of the Society an intention existed to collect engineering books and reports, for an Appendix to the Rules, printed in 1824, gives the titles of 77 books and maps as being then in the possession of the Society. Ten years later the Institution acquired by bequest the large and valuable library of its first President, Thomas Telford. Since then the additions by purchase and by presentation have been on a scale at least commensurate with the growth of the Society, till at the present time there are more than 15,500 separate volumes, besides about 420 volumes of pamphlets, and many duplicates. During the spring of this year the subject-matter catalogue was completely revised and brought down to date. Among the recent additions to the library is a valuable series of reports and State papers, presented by the Minister of the Waterstaat of the Netherlands, through the intermediary of H.E. the Netherlands Minister in London, Count Bylandt.

The Annual Reports for several years past have impressed upon the members the importance of continuing the needful development of the Library, so as to maintain unimpaired the advanced position of this unrivalled collection of engineering literature, and it is gratifying to find that on the whole the appeal has been well responded to. Efforts to keep the Library abreast of the literary

activity of the day, if confined to the staff of the Institution, would be inadequate. It is therefore imperative on the members to bear continually in mind, that it is their interest to co-operate with the officers, by suggesting the titles of important professional treatises not at present in the library, and more especially by presenting copies of their own works and printed reports as they are published. The casual visitor to the library, with half an hour at his disposal, will read with interest recent authentic information respecting a public undertaking which he has possibly seen or heard of, although he may not be disposed at the moment for the study of elaborate scientific or technical treatises. The interest thus aroused may often lead to after study and research, beneficial alike to the individual and to his professional brethren.

Since the date of the last Report further shelf accommodation has been rendered necessary, and some of the older books and series of periodicals have been removed to the galleries, in order to afford room for newer works. Applications have in the past year been made for copies of the printed evidence taken before Parliamentary Committees and before Arbitrators; and the reports of the Library Conference have been carefully perused with a view to the adoption of any practical suggestions. The Council are always willing to receive and, if practicable, to act upon recommendations for augmenting the efficiency of the library and the comfort of the readers.

Having now offered for the consideration of the members what are conceived to be the objects of the Institution, and having stated the manner in which those objects have been attempted to be carried out, it only remains to give an account of the operations and condition of the Institution during the past twelve months.

In the last session twenty-four Ordinary Meetings were held, at which sixteen Original Communications were read and discussed. The awards made by the Council to the Authors of some of these Papers have comprised Watt Medals and Telford Premiums to George Frederick Deacon[1] and James Nicholas Douglass;[1] Telford Medals and Premiums to James Bower Mackenzie and Adam Fettiplace Blandy; Telford Premiums to Edward Dobson, James Price,[1] and John Evelyn Williams; and the Manby Premium to John Purser Griffith. It will suffice to say that the subjects dealt with fairly represent the most important matters of interest now engaging the attention of engineers, as may be deduced from the length of the discussions. In addition to the memoirs read and

[1] Have previously received Telford Medals.

discussed, twenty-five other Papers were selected for publication in the "Minutes of Proceedings," and for some of these the following awards were made—Watt Medals and Telford Premiums to George William Sutcliffe and Edward Sang, and Telford Premiums to William George Laws and George Higgin.[1]

The Students' meetings have been continued as before, eight having been held during the last session. It is a matter of regret to the Council that they could not this year award a Miller Scholarship, and that the Papers were so few in number; but Miller Prizes have been bestowed upon Arthur Cameron Hurtzig,[2] Robert Henry Read, John Charles Mackay,[2] and Percy Wilson Britton.[2] While giving every credit to the manifest desire of the Students as a body to avail themselves of the Supplemental Meetings as a means of self-improvement, the Council wish to warn them of the danger of making their communications the vehicles either for mere notes of published matter, or for the enunciation of crude opinions on difficult problems. The topics most suitable to be treated by the Students are, as has been frequently pointed out, descriptive accounts of executed works.

During the past session the Council were engaged in effecting the separation of the professional from the non-professional Associates —a task rendered necessary by the terms of a Resolution passed at the Special General Meeting held on the 2nd of December, 1878, which Resolution was embodied in the Bye-laws then enacted. This task was one of considerable labour, the qualifications and antecedents of 1,670 Associates having to be separately considered. It was to be expected that in dealing with so many cases some Associates would fail to be satisfied, but the number of these has, the Council are glad to say, been fewer than was anticipated. Now they are enabled to report that in accordance with the instructions before referred to, 1,080 Associates have been transferred to the class of Associate Members, leaving a residue of 590 in the original class, who will however, in terms of the legal opinion quoted in the last Report, remain possessed of the privileges of corporate membership.

The elections have comprised M. Tresca as an Honorary Member, 40 Members, and 152 Associate Members, besides 23 Associates not entitled to the privileges of corporate membership; while 68 Associates have been transferred to the class of Members. On the

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[1] Has previously received a Telford Medal.

[2] Have previously received Miller Prizes.

other hand, the deductions have been: By death, 18 Members, 3 Associate Members, and 10 Associates; by resignation, 4 Members, 3 Associate Members, and 15 Associates; and by erasure, 7 Members, 5 Associate Members, and 6 Associates. It results from this statement that there has been an addition during the year of 1 Honorary Member, 79 Members, and 65 Associate Members or Associates, representing a total increase of 145. The gross numbers on the books on the 30th of November, 1879, were: 17 Honorary Members, 1,140 Members, 1,221 Associate Members, and 582 Associates (23 of the latter being non-corporate members), giving a total of all classes, irrespective of the Students, of 2,960.[1] This aggregate is more than double what it was twelve years ago.

The Council regret that during the last year death has removed many well-known engineers,[2] foremost among whom were their

[1] The following table shows the changes that have occurred in the several classes belonging to the Institution, irrespective of the Students, during the last two Sessions:

—	Session 1877–78.				Session 1878–79.				
	Honorary Members.	Members.	Associates.	Totals.	Honorary Members.	Members.	Associate Members.	Associates.	Totals.
Numbers on Nov. 30, 1877 and 1878 . . .	16	925	1,670	2,611	16	1,061	..	1,738	2,815
Transferred to Members . .	..	..	95		..	..	..	68	
Ditto to Associate Members	..	..	..		..	..	..	1,080	
Elections . .	..	56	205	261	1	40	152	23	216
Deaths . . .	..	13	20		..	18	3	10	
Resignations .	..	1	11	−57	..	4	3	15	−71
Erased from Register . . .	..	1	11	204	..	7	5	6	145
Numbers on Nov. 30, 1878 and 1879 . . .	16	1,061	1,738	2,815	17	1,140	1,221	582	2,960

[2] The deaths recorded during the year have been :—*Members:* William Baker, *Member of Council* (lv. 315); John Frederick Bourne (*post*, p. 289), Henry Orlando Bridgeman (lviii. 339); William Whitaker Collins (lviii. 340); Alfred Wingate Craven, John Sidney Crossley (lviii. 341); John Curphey Forsyth (lviii. 343); William Froude, M.A., F.R.S., *Member of Council*, George Hardinge, M.A. (*post*, p. 291); Richard Lionel Jones, M.A., *Lieut.-Colonel* John Pitt Kennedy (*post*, p. 293); Thomas Sopwith, M.A., F.R.S. (lviii. 345); John Taylor, William Thorold (lv. 321); Julian Horn Tolmé (lv. 319); Edward Brainerd Webb (lvii. 311); William West (*post*, p. 308); and Edward Leader Williams (lvii. 315). *Associate Members:* James Abernethy, Francis Dawson (*post*, p. 313), and John Hanvey (*post*, p. 314).

colleagues, Mr. William Baker, and Mr. William Froude, F.R.S. In the person, too, of Mr. Thomas Sopwith, F.R.S., the Institution has lost one of its oldest and most respected members.

The Student class now numbers 584, of whom 150 were admitted last session. During the year 42 Students were elected into the Institution, and 24 ceased to remain on the list, so that the net increase was 84.

In the statement of Receipts and Expenditure attached to this Report, a slight change has been made in the arrangement of the several sums on both sides of the account, with the object of showing at a glance, not only the total amount received during the financial year from all sources, but its separation into income proper, capital, and Trust Funds, with an analogous division of the disbursements. Of the gross sum of £15,158 18*s.* 6*d.* at the foot of the receipt side of the accounts, £929 0*s.* 10*d.* is the balance from last year; £10,960 11*s.* 9*d.* represents the income derived from Annual Subscriptions and from dividends on Institution investments; £2,837 12*s.* 6*d.* is the sum derived from the admission fees of new members and from life compositions; and £431 13*s.* 5*d.*, the dividends on Trust Funds. This latter item is less by £30 than at the corresponding period of 1878. This does not arise from any failure of dividends, but from the transfer of a part of the Miller Fund from Railway Debenture stock to Government stock, by which the interest on a sum of £3,000, constituting the original endowment, has been reduced from 4 to 3 per cent.

On the disbursement side of the statement will be found a balance of £14 5*s.* 1*d.* due to the Secretary on account of petty cash; £1,196 6*s.* 7*d.* represents house and establishment charges, including rent and taxes; £2,307 6*s.* 1*d.* salaries and wages; £1,249 9*s.* 4*d.* miscellaneous office expenses; £476 5*s.* 3*d.* main-

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Associates: Richard Secker Brough, (*post*, p. 315); John Brown, Charles Cammell, (lvi. 288); Sir William Fothergill Cooke, (lviii. 358); Thomas Barnabas Daft, (lv. 329); *Captain* Charles Wilson Faber, (lv. 331); James Henry Greaves (lvi. 289); John Rotheroe, and Edward Taylor Simpson (*post*, p. 317), and Alfred Terry (lvi. 290). The bracketed figures refer to the volumes of "Minutes of Proceedings" in which memoirs will be found.

The resignations have been accepted of the following:—*Members:* Charles Brumell, Edward Harris, Thomas Penn, and William Frederick March Phillipps. *Associate Members:* John Edwards Fraser, Richard Langrishe, and Alexander Robert Terry. *Associates: Major* Claes Adolf Adelsköld, Thomas Bell, William Bird, James George Aylwin Creighton, Joseph Schroder Croucher, Frederick Dresser, Norman Garrard, John Atkinson Harrison, William Henry Holland, William Randolph Innes Hopkins, Francis Ingram Palmer, *Colonel* James Puckle, *Lieut.-Colonel* John Lidstone Watts, R.E., *Lieut.-Colonel* Jackson Muspratt Williams, and George Henry Wood.

tenance of the library; and £4,568 19*s.* 3*d.* "Minutes of Proceedings." The investments on Institution account have been £4,093 1*s.* 2*d.*; the cost of premiums and prizes under trust, including investments on this account, came to £530 18*s.* 9*d.*; and a sum of £13 19*s.* was temporarily advanced to the Benevolent Fund for petty disbursements; while the balance of £708 8*s.* in the hands of the Bankers and of the Secretary, completes the total of £15,158 18*s.* 6*d.*

From this way of presenting the accounts it may be readily ascertained that the income has exceeded the ordinary expenditure by £1,134 1*s.* 2*d.*, and that the banker's balance is less by £220 12*s.* 10*d.* than it was twelve months ago. On the other hand, a sum of £1,255 8*s.* 8*d.* has been invested in excess of the capital receipts, and the payments on account of Trusts have been greater by £99 5*s.* 4*d.* than the receipts under this head.

The invested capital, representing the accumulated property of the Institution, has now reached £31,094 1*s.* 8*d.*, the interest on which is available for the general purposes of the Society, and constitutes rather more than one-tenth of the annual income. The Trust Funds, held for the purpose of awarding premiums, amount to £14,642 13*s.* 10*d.*, the whole of which is invested in Government stocks. Since the last Report, a sum of £4,093 1*s.* 2*d.* has been invested on Institution account, with which was purchased £1,000 Midland Railway Four per cent. Debenture stock, and £3,125 New Three per cents. It having been thought desirable that the whole of the Trust Funds should be placed in national securities, this latter stock has been taken to represent the reinvestment of the trust bequest of Mr. Joseph Miller, hitherto standing in £1,100 Great Eastern, and £2,000 Lancashire and Yorkshire Railway Four per cent. stocks, which latter stocks are now included among the Institution investments.

In the last Annual Report it was stated that the payment of local rates having been enforced by the parish, it had been determined to appeal to the Quarter Sessions, on the ground that the premises in the occupation of the Institution were exempt under the 6th & 7th Vict., chap. 36, had on the 3rd of November, 1843, been certified to be so by the Barrister named in the Act, and had since the date referred to enjoyed the exemption. That appeal was unsuccessful, as the Court confirmed the rate with costs, subject to a special case for the consideration of the Court of Queen's Bench. The special case was argued at length during the recent Michaelmas sittings, and in the result Mr. Justice Field and Mr. Justice Manisty delivered separate judgments confirming the rate with costs against the Institution. It will be for the

successors of the present Council to determine whether the matter shall be allowed to rest or shall be further prosecuted, it being understood that there is still a right of appeal to the Court of Appeal and subsequently to the House of Lords.

The munificent offer of Dr. Siemens, Member of Council, to contribute the sum of £10,000 to form the nucleus of a fund for providing a suitable building wherein the Applied Science Societies might be assembled under one roof, deserves the warmest acknowledgment. So far the proposed scheme has not been settled, and it will require most careful consideration. In any negotiations that may ensue for giving effect to this comprehensive idea, it will of course be necessary that care should be taken to preserve the individuality of this Institution.

The Council wish to remind the Members that the annual prize of £1,000, offered by His Majesty the King of the Belgians for the purpose of encouraging scientific research in matters concerning his kingdom, will in 1881 be open to competitors of all nationalities. The subject of the essay for that year is: "The best means of improving ports established on low-lying sandy coasts similar to those of Belgium." The memoirs must be forwarded to H.E. the Minister of the Interior, Brussels, before the 31st of December, 1880. The jury to be appointed to award the prize will consist of three Belgians and of four foreigners, and their names will be duly published according to custom. Having regard both to the intrinsic value of the prize, and to the liberal constitution of the jury for making the award, the Council trust that some of the members may be induced to take part in the competition, and thus to show their appreciation of the gracious intention of His Majesty in specially bringing the matter under the notice of this Institution, of which he is an Honorary Member. In international competitions of this kind British engineers have heretofore achieved marked distinction.

The Council believe that the present prosperous condition of THE INSTITUTION OF CIVIL ENGINEERS, which, both in its organization and in its method of procedure, is distinctly and definitely one dedicated to the promotion of science, may be taken as a convincing proof of the high esteem in which it is held; and they entertain a confident hope, that its scientific, as well as its practical and useful, character, may be as fully and as completely maintained in the future as in the years gone by.

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS.

Nominal £.	s.	d.	*Dr.*	£.	s.	d.	£.	s.	d.
			To Balance in the hands of the Treasurer				929	0	10
			INCOME.						
			— Subscriptions:—						
			Arrears	260	18	6			
			Current	9,097	7	6			
			Advance	87	3	0			
			— Publication Fund	20	1	3			
			— Library Fund	76	10	0			
			— Minutes of Proceedings:—Repayment for Authors' separate copies, &c.	193	1	3			
			— Dividends: 1 year on *Institution Investments.*						
4,750	0	0	Great Eastern Railway Four per Cent. Debenture Stock . .	186	0	10			
3,000	0	0	London and North Western Ditto	117	10	0			
1,500	0	0	London, Brighton, and South Coast Ditto	58	15	0			
3,000	0	0	North Eastern Ditto . . .	117	10	0			
3,000	0	0	Great Northern Ditto . . .	117	10	0			
3.000	0	0	Lancashire and Yorkshire Ditto	117	10	0			
3.000	0	0	Great Western Ditto . . .	117	10	0			
3,000	0	0	Caledonian Ditto	117	10	0			
1,000	0	0	Midland Ditto	0	0	0			
1,500	0	0	London, Brighton, and South Coast Railway Four and a Half per Cent. Ditto . .	66	1	10			
3,000	0	0	Manchester, Sheffield, and Lincolnshire Ditto	132	3	8			
1,344	1	8	New Three per Cents. . . .	39	9	8			
£31,094	1	8	Total nominal or par value.						
			— Interest on Deposit Account	14	16	11			
			— Sale of Old Materials	2	0	0			
			— Benevolent Fund, Petty Disbursements, 1878 .	21	2	4			
							10,960	11	9
			CAPITAL.						
			— Admission Fees	2,484	6	0			
			— Life Compositions	353	6	6			
							2,837	12	6
			TRUST FUNDS.						
			— Dividends: 1 year on *Telford Fund.*						
2,839	10	10	Three per Cent. Consols . .	83	8	2			
2,586	0	11	Three per Cent. Reduced . .	75	19	2			
2,377	10	5	Three per Cent. Consols (Unexpended Dividends) . .	69	16	10			
913	2	7	Three per Cent. Reduced (Ditto)	26	16	6			
8,716	4	9	Total nominal or par value.						
			Carried forward . .	£256	0	8	£14,727	5	1

from the 1st DEC., 1878, *to the* 30th NOV., 1879.

PAYMENTS.

Cr.	£.	s.	d.	£.	s.	d.
By Balance of Petty Cash due to the Secretary				14	5	1
General Expenditure.						
— House and Establishment Charges:—	£.	s.	d.			
Repairs	114	14	5			
Rent	658	7	0			
Rates and Taxes	58	7	7			
Insurance	41	16	6			
Furniture	10	0	0			
Light, Fuel, and Water for Engine . . .	126	6	2			
Tea and Coffee	50	2	4			
Assistance at Ordinary and at Students' Meetings	16	2	6			
Household Expenses	120	10	1			
				1,196	6	7
— Salaries	1,650	0	0			
— Clerks, Messengers, and Housekeeper	627	6	1			
— Donation to late Housekeeper	30	0	0			
				2,307	6	1
— Postage and Parcels	161	3	1			
— Stationery, including Printing Circulars, New Bye Laws, and Lists of Members . . .	645	6	3			
— Watt Medals	7	7	6			
— Diplomas	42	17	3			
— Annual Dinner (Official Invitations, &c.) . . .	144	14	6			
— Legal Expenses, *re* Rates . . . £113 17 11; „ *re* Bye Laws . . 134 2 10	248	0	9			
				1,249	9	4
— Library Books	297	10	6			
Periodicals	56	6	10			
Binding	122	7	11			
				476	5	3
— Publication, "Minutes of Proceedings" . . .	4,393	19	3			
"General Index" Vol. I. to Vol. LVIII. .	175	0	0			
				4,568	19	3
— Benevolent Fund, Petty Disbursements, 1879 .	..			13	19	0
				9,826	10	7
Capital Investments.						
£3,125 New Three per Cents.	3,000	0	0			
£1,000 Midland Railway Four per cent. Debenture Stock	1,093	1	2			
				4,093	1	2
Trust Funds.						
— Telford Premiums	243	12	8			
— Telford Fund: Balance of Income not yet Expended in Annual Premiums, invested in £50 8*s.* 2*d.* Three per Cent. Reduced	48	8	1			
— Manby Premium	12	14	9			
— Miller Scholarships	120	0	0			
— Miller Prizes	47	10	11			
— Miller Fund: Balance of Income not yet Expended in Annual Premiums, invested in £61 1*s.* 2*d.* Three per Cent. Consols.	58	12	4			
				530	18	9
Carried forward				£14,450	10	6

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

Dr.			RECEIPTS—*continued.*	£.	s.	d.	£.	s.	d.
			Brought forward . . .	256	0	8	14,727	5	1
			TRUST FUNDS—*continued.*						
To Dividends: *continued.*									
£.	s.	d.	*Manby Donation.*						
250	0	0	Great Eastern Railway Four per Cent. Debenture Stock . .	9	15	10			
			Miller Fund.						
3,125	0	0	New Three per Cents. . . .	91	15	10			
582	18	6	Three per Cent. Consols (Unexpended Dividends) . . .	17	2	6			
61	1	2	Ditto ditto (6 months) . . .	0	17	11			
1,355	14	11	Three per Cent. Reduced (Unexpended Dividends) . .	39	16	6			
5,124	14	7	Total nominal or par value.						
			Howard Bequest.						
551	14	6	New Three per Cents. . . .	16	4	2			
							431	13	5
							£15,158	18	6

SUMMARY OF INVESTMENTS.

	£.	s.	d.	£.	s.	d.
INSTITUTION INVESTMENTS				31,094	1	8
TRUST FUNDS—						
Telford Fund	8,716	4	9			
Manby Donation	250	0	0			
Miller Fund	5,124	14	7			
Howard Bequest	551	14	6			
				14,642	13	10
				£45,736	15	6

from the 1ST DEC., 1878, *to the* 30TH NOV., 1879.

PAYMENTS—*continued.*

Cr.	£.	s.	d.	£.	s.	d.
Brought forward . .				14,450	10	6
By Balance Nov. 30, 1879, viz.:—						
Cash in the hands of the Treasurer . . .	679	10	9			
" " Secretary . . .	28	17	3			
				708	8	0
				£15,158	18	6

Examined and found correct.

(Signed) ALFRED RUMBALL, W. B. LEWIS } *Auditors.*

JAMES FORREST, *Secretary.*
9 *December*, 1879.

PREMIUMS AWARDED.

Session 1878–79.

The Council of The Institution of Civil Engineers have awarded the following Premiums:

For Papers read at the Ordinary Meetings.

1. A Watt Medal, and a Telford Premium, to George Frederick Deacon,[1] M. Inst. C.E., for his Paper on "Street Carriage-way Pavements."
2. A Telford Medal, and a Telford Premium, to John Bower Mackenzie, M. Inst. C.E., for his Paper on "The Avonmouth Dock."
3. A Watt Medal, and a Telford Premium, to James Nicholas Douglass,[1] M. Inst. C.E., for his Paper on "The Electric Light applied to Lighthouse Illumination."
4. A Telford Medal, and a Telford Premium, to Adam Fettiplace Blandy, M. Inst. C.E., for his Paper on "Dock Gates."
5. A Telford Premium, to Edward Dobson, Assoc. M. Inst. C.E., for his Paper on "The Geelong Water Supply, Victoria, Australia."
6. A Telford Premium, to James Price,[1] M. Inst. C.E., for his Paper on "Movable Bridges."
7. A Telford Premium, to John Evelyn Williams, M. Inst. C.E., for his Paper on "The Whitehaven Harbour and Dock Works."
8. The Manby Premium, to John Purser Griffith, Assoc. M. Inst. C.E., for his Paper on "The Improvement of the Bar of Dublin Harbour by Artificial Scour."

For Papers Printed in the Proceedings without being Discussed.

1. A Watt Medal, and a Telford Premium, to George William Sutcliffe, Assoc. M. Inst. C.E., for his Paper on "Machinery for the Production and Transmission of Motion in the large Factories of East Lancashire and West Yorkshire."

[1] Have previously received Telford Medals.

2. A Watt Medal, and a Telford Premium, to Edward Sang, for his Paper on "A Search for the Optimum System of Wheel Teeth."
3. A Telford Premium, to William George Laws, M. Inst. C.E., for his Paper on "The Railway Bridge over the River Tyne at Wylam, Northumberland."
4. A Telford Premium, to George Higgin,[1] M. Inst. C.E., for his "Experiments on the Filtration of Water, with some Remarks on the Composition of the Water of the River Plate."

For Papers read at the Supplemental Meetings of Students.

1. A Miller Prize, to Arthur Cameron Hurtzig,[2] Stud. Inst. C.E., for his Paper on "The Tidal Wave in the River Humber."
2. A Miller Prize, to Robert Henry Read, Stud. Inst. C.E., for his Paper on "The Construction of Locomotive Boilers."
3. A Miller Prize, to John Charles Mackay,[2] Stud. Inst. C.E., for his Paper on "The Excavating of a Tunnel in Rock by Hand Labour and by Machinery."
4. A Miller Prize, to Percy Wilson Britton,[2] Stud. Inst. C.E., for his Paper on "The Design and Construction of Wrought-iron Tied Arches."

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[1] Has previously received a Telford Medal.
[2] Have previously received Miller Prizes.

SUBJECTS FOR PAPERS.

Session 1879–80.

The Council of The Institution of Civil Engineers invite communications, of a complete and comprehensive character, on any of the Subjects included in the following list, as well as on other analogous questions. For approved Original Communications, the Council will be prepared to award Premiums, arising out of special Funds bequeathed for the purpose, the particulars of which are as under:—

1. The Telford Fund, left "in trust, the Interest to be expended in Annual Premiums, under the direction of the Council." This bequest (with accumulations of dividends) now produces about £260 annually.

2. The Manby Donation, of the value of about £10 a year, given "to form a Fund for an Annual Premium or Premiums for Papers read at the meetings."

3. The Miller Fund, bequeathed by the testator "for the purpose of forming a Fund for providing Premiums or Prizes for the Students of the said Institution, upon the principle of the 'Telford Fund.'" This Fund (with accumulations of dividends) now realises nearly £150 per annum. Out of this Fund the Council have established a Scholarship,—called "The Miller Scholarship of The Institution of Civil Engineers,"—and are prepared to award one such Scholarship, not exceeding £40 in value, each year, and tenable for three years.

4. The Howard Bequest, directed by the testator to be applied "for the purpose of presenting periodically a Prize or Medal to the author of a treatise on any of the Uses or Properties of Iron, or to the inventor of some new and valuable process relating thereto, such author or inventor being a Member, Graduate, or Associate of the said Institution." The annual income amounts to rather more than £16. It has been arranged to award this prize every five years, commencing from 1877. The next award will therefore be made in 1882.

The Council will not in any case make an award unless a communication of adequate merit is received; but, on the other hand, more than one Premium will be given, if there are several deserving memoirs on the same subject. In the adjudication of

the Premiums no distinction will be made between essays received from a Member, an Associate, or a Student of the Institution (except in the cases of the Miller and the Howard bequests, which are limited by the donors), or from any other person, whether a Native or a Foreigner.

List.

1. The Causes of Slips in Rocks and in different Earths, and the conditions that induce treacherous ground in railway-cuttings, tunnels, and the sides of valleys near reservoir-banks.
2. The most useful Sections of Rolled Iron for structural purposes, having regard to economy of material combined with strength.
3. The present systems of making Steel for Railway purposes, and the properties and character of the material.
4. The Tempering of Steel, and the influence thereby produced on its strength.
5. Experiments on the Strength of Materials used in construction, with descriptions of the Testing Machinery employed to ascertain the same.
6. The various chemical and protective Solutions or Coatings for the surfaces of metal-work exposed to Corrosion, with instances of their use and durability.
7. The comparative effect of "dead" and "live" loads in straining materials and structures, with the factor of safety considered desirable for various proportions of such loads in different countries.
8. The Forms of Staging, Scaffolding, and Centering used for the support of structures during erection.
9. The modern practice of Bridge-building in Germany, especially with reference to the details of construction and the substitution of bar and angle iron for wide flange-plates.
10. The erection of large Bridges, with detailed descriptions of some of the more important examples of Rolling-over, Building out, Lifting bodily, &c.
11. The Design and Construction of a Steel Bridge, with particulars of the Weight and Cost, and of the tests to which it has been subjected, compared with an Iron Bridge of the same span.

12. The resistance to Traction of modern Vehicles on modern Roads.
13. The best system of Working Suburban Passenger Traffic on Railways.
14. A description of the various kinds of Fireless Locomotives in use on Tramways, and their relation in cost to traction by horses.
15. The increase of Resistance on Railway Curves, and recent expedients to diminish the same by lubricated tires, divided axles, loose wheels, or otherwise.
16. The Construction of Masonry Dams for, and of Tunnel Outlets from, Storage reservoirs.
17. The Flow of Water through Pipes and Conduits, with experiments in verification of the existing formulæ, and suggested amendments and improvements.
18. The Mechanical Separation and Chemical Treatment of Sewage, with analyses of the effluents and of the sludge, and statements of cost in proportion to population and rateable value.
19. The modes of regulating the action of Storm Overflow from Sewers, and the Flushing of Sewers.
20. The methods used for determining the Discharge of Rivers, with a description of the Floats and Current Meters employed for the purpose.
21. The Works carried out on the Continent of Europe for the Improvement of Rivers, and of Inland Navigation generally.
22. The apparatus and appliances for Working under Water.
23. The Relative Cost of Excavating under different conditions by Mechanical Appliances and by Hand Labour, with descriptions of Dredging Machinery and Plant.
24. The Design and Construction of Building Slips for large vessels.
25. The Construction of Tide Gauges, and the usual method of carrying out a systematic series of Tidal Observations.
26. The type of Steam Engine best adapted for ordinary factory purposes, in respect to economy in the use of steam, as well as in first cost, and in cost of maintenance.
27. The best method of Testing Steam Engines (independent of their boilers), having regard to accuracy of the results, and ease with which the tests can be carried out.
28. The modern practice in the design and construction of Boilers,
29. The use of Compressed Air as a Motive-power, particularly as applied to machinery in mines, and for traction on tramways and in tunnels.

30. The relative advantages of Steam, Heated Air, Gas, Water, and Electricity as the Motive-power in small Engines.
31. Wind and Water as Motive-powers, compared with Steam-power, and the Motors most suitable for utilising them.
32. The various descriptions of Pumps employed for Raising Water or Sewage, and their relative efficiency.
33. The different systems of Lifts in use in Warehouses and in Dwellings.
34. Marine Engine Progress, practically considered.
35. The special Construction of Vessels for the reception of Railway Trains on Deck, indicating the Arrangements for the shipping of such Trains on their own wheels at various states of the Tide.
36. The most suitable appliances and arrangements for Shipping Coal and other Minerals, both where the water level is fixed and where it is variable, and from wagons discharging from the end as well as from the bottom.
37. The relative Loss of Power due to Friction in various parts of Machinery.
38. The various classes of Lubricants, with records of Experiments, showing their relative values, and a description of the mode of testing them.
39. The Appliances and Methods used in different countries for Tunnel-driving, Rock-boring, and Blasting, with details and cost of the results attained.
40. The Methods and Machinery employed in Sinking and in Working deep Coal Mines.
41. Coal Depôts for Ocean Steamers, the various points involved in their management, and the methods of preserving large quantities of coal from deterioration.
42. The Methods employed in securing large and irregular-shaped mineral workings, for example—the Almaden Mines, the Great Comstock Lode, &c.
43. The combined use of Fire-brick, Iron, and other materials for resisting High Temperatures in Blast Furnaces, Kilns, Pottery Ovens, and similar structures.
44. The Disposal and Utilisation of Slags from various smelting processes.
45. The Management of Underground Waters in mining districts, and the relative economy of distributed or trunk pumping engines, adits, &c., in particular cases.

46. The Principles underlying the progress of Economy in Gas Production and Distribution, with recent Methods of Purification.
47. On proportioning Mains for the distribution of Water and Gas.
48. The Employment of the Electric Current for the Transmission of Sound, and the use of the Telephone for practical purposes.

Instructions for Preparing Communications.

The Essays should be written in the third person, and be legibly transcribed on foolscap paper, on one side only, leaving a margin on the left side, in order that the sheets may be bound. Every Paper must be prefaced by a concise Abstract.

Illustrations, when necessary, should be drawn on tracing paper, to as small a scale as is consistent with distinctness, and ready to be engraved. When an illustrated communication is accepted for reading, a series of Diagrams will be required sufficiently large and boldly coloured to be clearly visible at a distance of 60 feet. These Diagrams will be returned.

Papers which have been read at the Meetings of other Societies, or have been published in any form, cannot be read at a Meeting of the Institution, nor be admitted to competition for the Premiums.

The Communications must be forwarded to the Secretary of the Institution, from whom any further information may be obtained.

Charles Manby, *Honorary Secretary.*
James Forrest, *Secretary.*

The Institution of Civil Engineers,
25, *Great George Street, Westminster, London, S.W.*
October, 1879.

EXCERPT BYE-LAWS, SECTION XV., CLAUSE 3.

"Every Paper, Map, Plan, Drawing, or Model, presented to the Institution, shall be considered the property thereof, unless there shall have been some previous arrangement to the contrary, and the Council may publish the same in any way and at any time they may think proper. But should the Council refuse or delay the publication of such Paper beyond a reasonable time, the Author thereof shall have a right to copy the same, and to publish it as he may think fit, having previously given notice, in writing, to the Secretary of his intention. Except as hereinbefore provided, no person shall publish, or give his consent for the publication of any communication presented and belonging to the Institution, without the previous consent of the Council."

NOTICE.

It has frequently occurred that in Papers which have been considered deserving of being read and published, and have even had Premiums awarded to them, the Authors may have advanced somewhat doubtful theories, or may have arrived at conclusions at variance with received opinions. The Council would therefore emphatically repeat, that the Institution must not, as a body, be considered responsible for the facts and opinions advanced in the Papers or in the consequent Discussions; and it must be understood, that such Papers may have Medals and Premiums awarded to them, on account of the Science, Talent, or Industry displayed in the consideration of the subject, and for the good which may be expected to result from the discussion and the inquiry; but that such notice, or award, must not be regarded as an expression of opinion, on the part of the Institution, of the correctness of any of the views entertained by the Authors of the Papers.

ORIGINAL COMMUNICATIONS

RECEIVED BETWEEN DECEMBER 1, 1878, AND NOVEMBER 30, 1879.

AUTHORS.

Allan, W. No. 1,664.—Marine Engine Progress Practically Reviewed. With Diagram and Model.

Attwood, G. No. 1,652.—A Method of Working a South American Gold Mine belonging to the Potosi Mining Company. With 12 Drawings, and 16 Photographs.

Barret, M. No. 1,656.—Remarks on Movable Bridges. With 4 Sheets of Drawings (vol. lvii., p. 60).

Bauerman, H. No. 1,624.—On the Progress of Mining and Metallurgy in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874–78 (vol. lv., p. 297.)

Blackett, J. No. 1,671—New Zealand Lighthouses. With 8 Drawings.

Browne, W. R. No. 1,638.—Technical Report of the German Railway Union (vol. lvii., p. 208).

Brunton, R. No. 1,641.—Observations on the Effect of Cutwaters to Bridge Piers, placed in the Channels of Rivers; and of Splay-wing, or sustaining Walls, to the up-stream side of single-arch Bridges. With 1 Drawing.

Buckley, R. B. No. 1,646.—The Proper Construction of Irrigation Canals, so as to avoid Erosion or Silting, and to prevent the growth of weeds (vol. lviii., p. 278).

" No. 1,670.—Movable Dams in Indian Weirs. With 11 Drawings.

Carson, W. No. 1,643.—The Passenger Steamers of the Thames, the Mersey, and the Clyde (*ante*, p. 82).

Chance. J. T. No. 1,640.—Dioptric Apparatus in Lighthouses for the Electric Light (vol. lvii., p. 168).

Chatterton, G. No. 1,668.—The Main Drainage of Torquay. With 2 Drawings.

Clark, D. K. No. 1,602.—On the Progress of Machinery in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874–78 (vol. lv., p. 286).

AUTHORS.

Clark, D. K. No. 1,654—The St. Gothard Tunnel: Second Paper. (vol. lvii., p. 239).

Clericetti, Professor C. No. 1,680.—The Theory of Modern American Suspension Bridges.

Colson, C. No. 1,669.—Portsmouth Dockyard Extension. With 28 Drawings.

Conder, F. R. No. 1,676.—On the Comparative Cost of Transport by Railway and by Canal.

Courtney, E. H., Major R.E. No. 1,659.—On Cushing's Reversible Level. With 2 Sheets of Drawings (*post*, p. 278).

Cunningham, G. C. No. 1,651.—Description of a Rail Truss Girder designed for the Prince Edward Island Railway, Canada. With 1 Drawing.

Deacon, G. F. No. 1,634.—Street Carriage-way Pavements (vol. lviii., p. 1.)

Delano, W. H. No. 1,673.—On the Use of Natural Asphalt and Bitumen in Engineering Works. With 1 Drawing.

Douglass, J. N. No. 1,639.—The Electric Light applied to Lighthouse Illumination. With a series of Diagrams and small scale Drawings (vol. lvii., p. 77).

Duckham, F. E. No. 1,622.—The Thames Steam Ferry between Wapping and Rotherhithe.

Ende, M. am. No. 1,637.—On the Limiting Spans and the Depths of Girder Bridges.

Errington, W. No. 1,657.—Description of Graving Dock, Auckland, New Zealand. With 4 Sheets of Drawings, and 3 Photographs.

Gaudard, J. No. 1,648.—On the Fundamental Types of Metal Bridges.

Gower, C. F. No. 1,625.—Abingdon Sewerage. With 7 Drawings.

Hayter, H. No. 1,667.—The Amsterdam Ship Canal.

Higgin, G. No. 1,644.—Experiments on the Filtration of Water, with some remarks on the Composition of the Water of the River Plate (vol. lvii., p. 272).

Higgs, P. No. 1,604.—On Progress in the Application of Electrical Science to Engineering Purposes in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874–78 (vol. lv., p. 308).

Howarth, O. H. No. 1,635.—Wood as a Paving Material under Heavy Traffic (vol. lviii., p. 31).

AUTHORS.

Josephson, J. P. No. 1,661.—The Construction of a Self-registering Tide Gauge (vol. lviii., p. 441).

Keefer, S. No. 1,675.—Notes on the Economy of Inland Navigation.

Kinahan, G. H. No. 1,623.—The Travelling of Sea Beaches (vol. lviii., p. 281).

Lupton, A. No. 1,665.—The Bettisfield Colliery.

Millar, W. J. No. 1,626.—On the Strength and Elasticity of Materials (vol. lviii., p. 222).

Ormsby, A. S. No. 1,674.—On Artificial, or Non-absorbing Collecting Surfaces for Pure Water.

Peppercorne, F. S. No. 1,678.—Irrigation and Canalization Works, Ancient and Modern.

Rapier, R.C. No. 1,631.—Brief Account of the Woosung Railway (*post*, p. 274).

Redman, J. B. No. 1,672.—The River Thames.—Tides 1876, 1877, 1878. Supplementary Memoir (*post*, p. 286).

Sandeman, J. W. No. 1,663.—Experiments on the Resistance to Horizontal Stress of Timber Piling (*post*, p. 282).

Sang, E. No. 1,620.—A Search for the Optimum System of Wheel Teeth (vol. lvii., p. 248).

Scott, Major-Gen. (R.E.), and Redgrave, G. R. No. 1,649.—The Manufacture and Testing of Portland Cement. With 5 Diagrams.

Shelford, W. No. 1,639A.—Note on a Graphic Mode of ascertaining the Flow of a Mill Stream (vol. lviii., p. 337).

Siccama, H. T. H. No. 1,666.—On the Construction of Foundations in British Guiana.

Squire, J. B. No. 1,650.—An Account of Earthwork Slips in the Cuttings and Embankments of various Railways during the past ten years, with their Causes and Modes of Treatment.

Smith, Graham. No. 1,645.—The Effect of Sulphates on Lime Mortar. With 12 Diagrams.

Stoney, B. B. No. 1,633.—Description of a new Balance Bridge over the Royal Canal at Dublin (vol. lviii., p. 285).

Sutcliffe, G. W. No. 1,621.—Description of Machinery for the Production and Transmission of Motion in the large Factories of East Lancashire and West Yorkshire (vol. lviii., p. 227).

Thomas, W. H. No. 1,677.—Wrought Iron Girders and Roofs. With 7 Drawings.

AUTHORS.

Vernon-Harcourt, L. F. No. 1,599.—On the Progress of Public Works Engineering in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874–78 (vol. lv., p. 275).

" " No. 1,655.—Fixed and Movable Weirs. With a Series of Diagrams, and 3 Sheets of Tracings.

Vidler, M. No. 1,681.—On the Formation of Shingle Beaches.

Warner, R. No. 1,679.—Description of a stone Breakwater at Walton-on-the-Naze. With a Model.

Washington, F. P., Capt. R.E.—No. 1,628.—On the Mapping of a District with reference to a Central Meridian (vol. lvi., p. 281).

Westland, D. M. No. 1,629.—The Calder Viaduct on the Wishaw line of the Caledonian Railway. With 3 sheets of Drawings.

Wood, C. J. No. 1,660.—Tunnel Outlets from Storage Reservoirs. With 4 Sheets of Drawings (*ante*, p. 37).

LIST OF DONORS TO THE LIBRARY.

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Kinder, Claude William	2	2	0
Kinder, Major Thomas William	2	2	0
Kingsley, Maurice	2	0	0
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Rofe, Henry	2	2	0
Sells, Charles	3	3	0
Shaw, Arthur Edward	3	3	0
Shawe, George Augustus Grant	1	1	0
Spindler, Henry Lewis	1	10	0
Tait, James	2	2	0
Watts, George Kempthorne	2	6	0
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Wilson, Robert Edward	1	1	0
	76	10	0

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*** *This Council will continue till December* 1880.

Sect. II.—OTHER SELECTED PAPERS.

(*Paper No. 1564.*)

"The Corbière Lighthouse, Jersey."

By Imrie Bell, M. Inst. C.E.

The employment of concrete as a building material, though extensively adopted by the Romans, had for many centuries afterwards fallen out of use and become obsolete. On the resuscitation in modern times of this art of building, its use was almost entirely confined to the formation of a monolithic mass underground, to serve as a foundation for the stone or brickwork of the superstructure. French engineers appear to have been foremost in appreciating the value of concrete, for sea works. During the earlier period of its employment for such works, the natural hydraulic limes were used as the cementing material, with the addition of puzzolana. Afterwards, from the valuable and exhaustive researches of Vicat, and the progressive improvements made in the manufacture of Portland cements, a vast impetus was given to the introduction of this art in the construction of buildings of all descriptions. Concrete can be made, under almost any circumstances, at a moderate cost; it is easily formed into any shape of block that may be desired; it can frequently be deposited in moulds in the exact position it is permanently intended to occupy; and, when carefully made, with a proper admixture of materials, which is a matter of vital importance, experience has proved that it possesses ample strength and durability under the most trying circumstances. There may be cases in which it might not be advisable to use concrete as a building material; and an engineer requires to give careful consideration to locality, the various kinds of materials available, cost of labour, carriage, and many other matters, before coming to a decision as to the material most suitable for the construction he has in view. The Author has been much struck by the want of attention paid to the art of producing a fair and finished surface in the exposed faces of concrete, as exemplified in many of the large engineering works in course of construction, where the exposed face has a honeycombed appearance, as well as the marks of the rough timber planks forming the frames in which the concrete has been placed. The Author has given this matter much con-

sideration, and the result of his experience is that, in concrete building, it is easy with a little attention not only to produce a fair surface, but to form mouldings, and even tracery and ornament, and at the same time to make the facework as durable as any other part of the block.

There appear to be two reasons why but little attention has hitherto been paid to this art; first, carelessness or indifference to appearance; secondly, that most of those who have attempted it have done so by rendering with plaster or by grouting with liquid mortar, both objectionable and dangerous modes of effecting the object. These are at the best only a veneering liable to sudden decay, and the failure (generally occurring after wet and frosty weather) has naturally stopped a repetition of the attempt.

The plan which the Author has followed in harbour walls, both above and below low water, exposed to frost, heat, storm and rain, with complete success and at an inappreciable increase of cost, is to have a smooth planed board for the face of the mould, painted over previous to commencing the work with a mucilage of soap to prevent the mortar adhering. In filling the frame, care must be taken that a finer mixture of concrete or coarse cement mortar be laid in with a trowel close to the face board, as the work proceeds, so that the mixture is carried up uniformly with that contained in the body of the work, the whole forming one homogeneous mass, and ensuring the setting process of the whole mass being carried out simultaneously, so that the face is, in fact, like the skin of an iron casting, and actually the strongest portion of the mass. It is intended, in this Paper, to give a description of the construction of the Corbière lighthouse, which the Author believes to be the first of the kind in the British Islands made of Portland cement concrete. It was erected by him as executive engineer for the States of Jersey, from the design of Sir John Coode, M. Inst. C.E.

The Corbière rock, upon which the lighthouse is erected, lies off the south-western point of the island of Jersey (Fig. 1), in latitude 49° 10′ 40″ north, longitude 2° 14′ 50″ west. It is distant from the mainland about 1,600 feet, is isolated at high water of all tides, but is accessible over a ledge of rocks, shortly after half ebb tide up to nearly half flood of each tide, when the sea is smooth —not a matter of frequent occurrence in this exposed part of the island. This has rendered necessary, as one of the works connected with this undertaking, the construction of a causeway, to ensure the safety of the lightkeepers on their passage to and from the lighthouse. The range of tide on this coast is 32 feet at ordinary springs, and 23 feet at ordinary neaps.

Road of access, and Keepers' Houses.

The site chosen for the lighthouse being inaccessible, by land, rendered it necessary to commence operations by the formation of a road of access, extending over ½ mile in length; and along with this were constructed dwelling houses on the mainland for the lightkeepers, with the necessary storehouses and outbuildings; but there is nothing in this section of the works worthy of special notice.

Tidal Causeway.

The formation of the tidal causeway, over a ledge of rocks exposed to the full force of the swell of the ocean, although a subsidiary work, required much consideration. This causeway had to be built over a very irregular surface, full of deep pools and fissures. Owing to its submergence at each tide, the time during which operations could be carried on was limited, and they could only be proceeded with from the shore end, which retarded the rate of progress that might otherwise have been made. It exceeds ¼ mile in length, is 6 feet in width at the top, and is formed of two side walls built of granite blocks, with a batter on the sides of 1 to 2, the height varying from 1 foot to 8 feet; the blocks are hammer-dressed on the face, and laid on level beds in cement mortar. The space between the walls is filled with Portland cement concrete, in the proportion of 8 parts of shingle and coarse sand to 1 part of cement; the upper 8 inches being made stronger and finer, in the increased proportion of 4 parts of shingle to 1 part of cement.

The action of the sea during gales prevents any great accumulation of sea weed upon the surface of the causeway; and a sprinkling of hot lime in calm weather, afterwards brushed off with birch brooms, is found sufficient to prevent any growth.

Arrangements for the Transport and Landing of Building Material.

The most important consideration connected with the arrangements for the construction of the tower was to devise a scheme for transporting the materials to the rock and landing them upon it, as this point, it was seen, would materially influence the cost of the works. The question being whether to take the material overland to some convenient point on the shore, or to transport it by sea; in either case there was no possibility of landing it upon the rock itself because the sea at this point of the

coast is seldom still. When the tide commences to flow there is always a heavy swell, which upon so rough and rocky a coast renders it an impossibility to moor a barge with material close to the rock for the purpose of loading or discharging. This, therefore, entailed the necessity of landing the material at the nearest point on the mainland where a sheltered spot could be obtained; in fact, except in calm weather, it is unsafe to approach the rock even by a rowing boat, after the causeway is covered. In stormy weather the waves are carried to a great height; for instance, on the completion of the lighthouse, during a storm in December 1876, a body of water was carried up the gully, and broke up the concrete platform placed 15 feet above high water spring tides, at the site of the temporary workshops and stores, and conveyed portions of it, weighing from 3 to 4 tons, over the side of the rock. The lightkeepers stated that sheets of spray during the same storm were thrown over the top of the lighthouse, or to a height of 136 feet above high-water mark.

After giving the whole matter full consideration, the Author decided upon conveying all the material by sea from St. Helier. One circumstance which materially influenced him in this decision was, that he had already constructed a depôt and barge harbour at St. Helier, for the supply of concrete for the harbour and breakwater then being constructed, at which large quantities of gravel, sand, and cement, were landed and stored, besides having at command the barges and tug boats employed upon that undertaking. Thus a constant and regular supply of material could always be depended upon; all that was required to complete the arrangement being an accessible and sheltered place near the site of the lighthouse, to which the material could be with safety transferred. Fortunately a bight to leeward, in the lower part of the rock upon which the tower was to be erected, gave access to a bay of deep water, accessible at all states of the tide, and in close proximity to the spot which had been fixed upon for placing the workshops, stores, and concrete-mixing platform. At a distance of about 80 yards outside this spot there was a patch of rocks, uncovered at high water of neap tides, leaving a channel between, with from 10 to 14 feet depth of water at low water of spring tides, which formed a natural harbour, convenient for the handling of barges and a steam tug, so long as they did not approach too close to the rocks on either side. The assistance afforded under this arrangement by the depôts and plant of the St. Helier harbour, in keeping up a constant supply of materials, by an easy mode of carriage to the lighthouse works, made a most important saving

in the cost of construction, as otherwise the whole of the material, except the stone and a small portion of the sand, must have been carted a distance of rather more than 8 miles, the last ½ mile over uneven boggy ground, there being no road. This would also have entailed the necessity of unloading carts on the mainland, and reloading into trollies for transport across to the rock, which, as already explained, could only be effected at certain states of the tide, and in calm weather, and would have rendered it necessary to delay the work of construction until the causeway across the ledge was completed, thereby causing a great sacrifice of time; whereas by barge and steam tug from St. Helier, a similar distance, the material could be landed direct at the works on the rock itself. Under this arrangement the construction of both lighthouse and causeway was carried on simultaneously. The landing of the material from the barges on their arrival from St. Helier, when moored in the deep-water channel, was carried out by an overhead ropeway from the main rock (at the foot of which were the stores and workshops) to the patch of rock on the opposite side of the channel, care being taken that sufficient headway was allowed for working the barges underneath (Figs. 2, 3, 4). The rope suspended between the two rocks formed the rail or ropeway. The apparatus consisted of a single wheel with a grooved tire, which travelled on the rope, supporting a block and tackle by two side cheeks for adjusting the height, with a hook for carrying the bag or basket of material. This wheel with tackle was pulled along the ropeway by a small endless wire rope wound round a drum, worked with a small windlass by two men. An improvement was effected, by having a double rope from the landing platform out to a little beyond the position where the barge was intended to be moored, where the ropes were fastened to a cross bar, and from thence continued to the patch of rock by a single rope, which, in order to give additional height, was passed down to the rock over a pair of sheer legs. A double line of ropeway was thus formed, from the position which the barge would occupy when moored, to the landing place on the main rock. The main rope, secured to an eye-bolt lewised into the rock, was stretched from the apex of the sheer legs over the position of the barge; at this point it was secured to the centre of the cross bar, from the ends of which two ropes were fastened, and carried parallel to each other to the main rock, and firmly secured to it, after passing over the guide pulleys. At the ends of the ropes blocks and tackles were placed, to tighten or slacken them as might be required; and upon these ropeways the travelling wheels, or gins, with sus-

pended tackle and hooks for carrying the baskets or bags of material, were run to and fro by means of the light endless wire rope, worked by the windlass. The wire rope (Figs. 5, 6, 7, 8, 9, 10), after two turns round the drum, passed up over a guide pulley, and was fastened to one of the gins or travelling wheels; it was then conveyed under one of the ropeways, and round a guide pulley fixed to cross bars. Returning under the other ropeway, it was fixed to the other travelling wheel, and carried on to the shore or main rock, over a guide pulley, and round the drum; so that while the loading at the barge end was being proceeded with, the unloading at the shore end was going on at the same time. The wheels, drums, &c., had been previously employed for other purposes; by being brought into use for this work, the expense of providing new apparatus was saved. As fast as the material was landed it was removed by wheelbarrows, along roads consisting of planks firmly spiked to cross sleepers, attached to upright poles fixed to the rock at distances suited to the length of planks, and extending from the landing stage up to the cement shed and concrete-mixing platform at the depôt.

At the depôt there was, besides smiths' and carpenters' shops, stores, and office, a barrack for the men, fitted up with sleeping bunks round the sides, with hammocks swung in the centre.

Lighthouse.

The platform upon which the lighthouse is erected is 9 feet high, and is formed of three courses, from which the tower, with moulded base and cap, rises. This tower is surmounted by a balcony having an iron railing, above which is the lantern provided with a dioptric illuminating apparatus of the second order, showing a fixed light extending over an arc of 250°. The dark angle, of 110°, towards the shore, is occupied by a dioptric mirror.

From seaward, between the bearings of south by east through east, to north by west, the light is white. Inshore of the eastern limits of the white light two sectors of red light are exhibited—one to the north-eastward, for marking the shoal ground of the Rigdon bank, and thence landwards; the other to the south-eastward, marking the Vrachères and the adjacent dangers landwards, through angles of 32° and 38° respectively. The red arcs are produced by shades of ruby glass attached to the lantern, which is 7 feet in height. The light is 135 feet above the mean level of the sea, or 119 feet above high-water of ordinary spring tides, and is visible for a distance of more than 18 miles. The

lamp is a pressure one, with the weights arranged below the body. The burner is of the Trinity House type, has three concentric wicks, consumes paraffin oil, and gives a light of about 200 standard candles. The lantern, by Messrs. Chance, is of the ordinary construction, except that the wall of the tower is carried a little higher than usual, and that the cast-iron pedestal is reduced by an equal amount. The inside diameter of the lantern pedestal is 10 feet. Outside a fog-bell, weighing 5 cwt., is fixed, by means of a wrought-iron plate bracket, strengthened with angle-irons, and stayed to the masonry of the tower.

Construction (Figs. 11, 12, 13, 14, 15).

In the construction of the lighthouse tower the difficulty of commencing the foundation under, or at low-water level, was not experienced, as in this case the level of the base of the platform was 100 feet above low-water; but difficulties of another kind nearly as serious had to be contended with in getting the material conveyed to this height over the intervening obstacles, and so as to construct the work expeditiously and economically. It was originally intended to build the tower with blocks made on the mainland, and carried over the tidal causeway by trollies; but this plan was given up for the reasons previously stated, and it was arranged to lay the concrete *in situ*. All the material had to be conveyed from the concrete-mixing floor at the level of the workshop, which was fully 50 feet below the bottom of the platform, to the top of the rock, and then hoisted to the course under construction. To accomplish this, an inclined railway, with siding on the 3-feet gauge, was laid upon longitudinal timbers, fixed firmly to uprights secured to the rock, from the concrete-mixing platform at the depôt up to the site of the tower. Here a steam hoist was erected, and so arranged that when the trolly, with tipping skip was hauled up to the top of the incline, it was in position for direct lift, which was effected by unhooking the chain from the trolly and attaching it to the skip, when it was hoisted to the height required. The rod chain suspended from the traveller at the top of the scaffold, adjusted to proper length by removing or adding a link rod to suit the courses of the masonry of the tower, was then attached to the hook of the skip, the crab chain was slightly slackened, and its hook relieved, and the skip was run forward over the centre of the tower, and the material tipped on to the banker, which completed the operation. The empty skip was drawn back into position for lowering by the counterbalance weight, the crab chain hooked to it and wound up

a little in order to relieve the rod-chain, which was detached, and the skip was then lowered on to the trolly and run down the incline. During the time thus occupied another skip was being filled upon the trolly on the siding at the foot of the incline, and was ready for hauling up on the return of the empty one, an arrangement which allowed the work to go on smoothly and continuously. The scaffolding was made of timber, strutted and braced, and securely guyed with wire ropes to the rocks below.

The top of the rock was roughly quarried for the bed of the platform, leaving a core about 13 feet in diameter and 7 feet in height. The mould, a segment of one-eighth of the circle, 3 feet in height, dressed on the face to a radius of 7 feet 9 inches, and a batter of 1 in 12, was fixed in place by tie-bolts lewised into the rock. The concrete, composed of 6 parts of shingle and coarse sand to 1 part of Portland cement, was then thrown in to the level of the top of the segmental frame, and the operation was repeated by shifting the frame round, until the course was complete. The second and upper courses were laid in a similar manner. The circular platform was 29 feet 6 inches in diameter at the top, and 9 feet high. The chamfered joints were formed by fillets tacked on to the face of the frame, and when the work was stripped of the frames, the third day after depositing the concrete, the face presented an appearance equal to dressed ashlar, and as hard as a soft brick. Instead of dowels and joggles, a batten was fixed upright at each end of the frame, so that when the concrete was filled in, and the batten removed, it left a vertical slot at each joint, about 9 inches long by 4 inches wide, the full depth of course, which was filled in, and formed part of the adjoining block, when the frame was shifted horizontally round, and again filled with concrete. A concentric channel, 9 inches broad by 4 inches deep, was left in the upper surface of each course, for a similar purpose. This was filled up with the concrete forming part of the course above, so that the whole structure was bound together as one stone. In order to give a smooth face to the work, care was taken that the Portland cement mortar, the proportions of which were 3 to 1, was laid close to the face of the mould, from 2 to 3 inches thick, and carried up with the concrete or rubble-work at the same time, to ensure equal setting and uniform colour. To prevent the mortar adhering to the face of the mould, soap, boiled with water to the consistency of cream, and applied immediately before the work was commenced, proved most satisfactory. The face moulds, which were made of pitch pine, were first washed thoroughly clean, and then thickly painted with the soap solution by a whitewasher's brush.

Upon the top of the platform the tower (Figs. 16, 17, 18) was carried up in the same manner as previously described—with the exception that the mould frames were made to radiate from the iron centre of a frame, firmly wedged and secured within the wall of the tower—building simultaneously two blocks, which formed opposite sectors, and completing the circular course in four shifts. The height of the tower and platform is 44 feet; the well of the tower is 11 feet in diameter, and the thickness of the shell varies from 2 feet 6 inches, under the cavetto at the cap, to 4 feet 3 inches at the plinth mouldings; the base is 5 feet 3 inches thick. There are two floors with three landings, as the work was designed for three floors. The girders for the floors are of rolled wrought iron, and were built into the side walls as the work proceeded. The floors are formed of ⊥ irons resting on the girders, and built into the side walls; the spaces between, and for $1\frac{1}{2}$ inch above the irons, are filled with fine cement concrete, in the proportion of 4 parts of shingle and sand to 1 part of cement.

In the centre of the tower a hollow cast-iron column, 13 inches in diameter and $\frac{5}{8}$ inch thick, in four lengths, is built into the platform; the ends of each length terminate with circular flanges, which are securely bolted together. The top length is bolted to the under side of the pedestal of the optical apparatus which it supports. The partition of the watch-room is made of wrought-iron plates $\frac{6}{16}$ inch thick. There are five windows; the openings for these and the door were made by fixing wooden centres formed to the required shape and boarded over, and the concrete filled in with the courses through which they pierced. The staircase consists of two wrought-iron spiral stringers, made of flat-iron, 7 inches long by $\frac{3}{8}$ inch thick, with angle irons 2 inches by $\frac{3}{8}$ inch thick, riveted to the upper and lower edges. The stringers are firmly bolted to the floor of the tower, and to the girders and cantilevers at the landings. The risers and supports are of flat bar iron, $2\frac{1}{4}$ inches deep by $\frac{1}{16}$ inch thick, riveted to the upper angle iron of the stringers; the tread plates are of cast iron, with grating panels. The balusters are of polished wrought iron, $1\frac{1}{2}$ inch in diameter, with bright brass caps and handrails.

The lantern pedestal is of cast iron, securely fastened to the masonry of the tower by twelve $1\frac{1}{4}$ inch holding-down bolts, 3 feet long. The inside is lagged with American yellow pine, and fitted with brass circular ventilators; the service galleries are of cast iron; the inclined framing for supporting the roof is of wrought iron, faced with gun metal; the cupola is of copper, double lined, surmounted by a copper revolving cowl with vane. An outside ladder is fixed

to the roof, and a lightning conductor is carried to the foot of the tower, and down a fissure in the rocks beneath into a deep pool, which is submerged at high water of all tides.

After the removal of the inclined railway and scaffolding of the tower, the approach was formed by cutting steps out of the rock, and in some instances by forming them of concrete, protected to windward by a rough-built rubble wall in cement mortar, with stones quarried from the adjacent rocks, with which it corresponded in appearance when finished.

The survey and sections for this work were completed in February 1873; the masonry of the lighthouse and half-tide causeway was finished in November of the same year, and the light was exhibited for the first trial on the 24th of April, 1874.

The expenditure, including all labour, materials, plant, and tools, and freight and charges for superintendence and engineering, &c., was:—

	£.
Half-tide causeway from mainland to lighthouse, including approaches at each end, and stairs up face of rock to foot of tower	1,606
Lighthouse structure complete, including wrought-iron staircase, girders, floors, and general fittings . .	2,976
Lantern and apparatus fitted in place, including fog bell and clock	2,555
Lightkeepers' dwellings and oil stores, with wrought-iron tanks	864
Total cost	8,001

The quantity of paraffin oil (which was supplied by Messrs. Young and Company) consumed was 2·26 gallons in every twenty-four hours, calculated from quantities specially measured during a period of six months. The total cost of maintenance, including wages, oil, stores, coal, &c., is about £170 per annum, taken from an average of two years.

The Paper is illustrated by several drawings, from which Plate 9 has been engraved.

(*Paper No. 1590.*)

"The Delta of the Rhine and the Meuse in the Netherlands."

By Harco Theodorus Hora Siccama, M. Inst. C.E.

The kingdom of the Netherlands consists of the eleven provinces of Friesland, Groningen, Drenthe, Overijssel, Gelderland, Utrecht, North and South Holland, Zeeland, North Brabant, and Limburg. It is bounded on the north and west by the North Sea, on the east by Germany, and on the south by Belgium. The soil consists of, 1st, the western continuation of the German glacial diluvium; 2nd, a belt of sand dunes on the sea coast; and 3rd, between these, alluvium: mixed sand, clay, silt, and peat, from the rivers Rhine, Upper Meuse, and Scheldt, forming the delta of these rivers. In Limburg the carboniferous formation is met with. The most productive and important parts of the country are the low lying alluvial districts, which are in most places below the level of the sea and river floods. They are guarded against encroachments of the ocean and rivers by high and massive embankments and dykes. A comparatively unimportant area is drained naturally into the rivers and estuaries; the remainder,—reclaimed fens and morasses, lakes and old river-beds, now forming deep and fertile polders (some of them 5 to 6 mètres below mean sea-level),—is kept dry by pumping. These rich lands owe their prosperity to silt deposited by the rivers, which are also the roads that bring commerce and traffic to the towns. Danger from the sea through high tides[1] may be obviated, but the rivers carry an element of destruction with them that no foresight or care can avoid. When, after severe frost, the ice breaks up, and in floating down meets with an obstruction, such as a shoal, a sharp bend, or an old wreck, the following shards press up, run aground, and, accumulating rapidly, form a dam across the river, choking its bed. The water then rises above the ice-dam till it overtops the dykes, and inundates the low country. The rivers, therefore, are a subject of constant attention; and the repairs and maintenance

[1] A table of the tides for some places on the North Sea coast, and the estuaries of the Rhine, is given in the "Pocket Book" of the Royal Engineers of the Netherlands.

of the dykes and the drainage arrangements are entrusted to the riverside owners and inhabitants and their local boards, under supervision of the Government department of public works called the Waterstaat. This corps is also directly in charge of the river beds between the dykes, and the navigation works, hydrography, and pilotage, and in times of danger and urgency is invested with unlimited power in matters pertaining to the department.

In the Roman period the country was covered with dense forest; and the inhabitants lived on the higher parts, or on artificial mounds, of which many still remain. The oldest village churches are often built on these mounds, having taken the place of the ancient temples of Thor or Freya.

As the population increased, the higher lands were embanked. There is evidence of the existence of dykes even in the second century, but in the eighth and ninth centuries large tracts had in this way been poldered. Sea dykes in the more exposed situations were in those early times defended on the outward slopes with reeds, rushes, and straw, and later on with seaweed,[1] gathered in the estuaries and salt-water meres. In the tenth and eleventh centuries the dykes had attained great importance and considerable dimensions, and were under the special care of the reigning princes. Vast improvements in the construction of machines for raising water led to poldering lower land than before. Seaweed was not considered suitable in many cases, and from 1466 the principal dykes were strengthened on the outside by rows of piling. About this time attention was turned to the reclaiming of the deeper basins, old meres and pools, and such fens as had been excavated for peat, the staple fuel of the country; and since then many polders and so-called *droogmakerijen*, or reclamations, have been made, and the whole country may now be said to consist of polders, each a little republic in itself. In most cases these polders are combined in groups having common interests into a *waterschap*, to bear jointly the expenses of dykes and drainage.

The dykes along the rivers are called bandykes, and are so constructed as not to be overflowed by the highest spates. These bandykes, which are of great importance to the well-being of the country, are often high and massive, and costly in construction, maintenance, and repair, and are guarded against destruction as long as possible. If at any spot the river reaches the top of the

[1] Zostera marina.

dyke, another dyke is laid on this again, called a *kisting*, and is made of anything at hand, hay, straw, dung, and even furniture, bedding, and buildings. When the river rises above a certain height, or as soon as the ice begins to appear about 1 to 1½ mètre (3¼ to 5 feet) under the so-called *noodpeil* or top of the dyke, the "dijkleger," or dyke army, is called out, and all the able-bodied male population is ready to rush to the places of danger; the whole extent of the dyke is constantly and vigilantly watched, and information immediately given of any suspicious occurrence. Besides the dangers from ice, the dyke may fail through an unsafe subsoil; the river forcing a passage through a sand stratum under the dyke, and bursting up inside the polder, forms what is called a *kwel*, which, if left alone, would soon undermine the bank. The dyke may also fail from bad workmanship, by having been often raised gradually and with unsuitable materials, no other being obtainable; and after continual wet weather it may at last give way and sink into the almost liquid subsoil, or *staal*. Another cause of danger, which exists all the year round, is that of the river attacking the dyke under water, when the deep-water channel approaching the bank at last undermines it. An occurrence of this kind, named a *schaardijk*, is provided against by *zinkstukken* or *bleeslagen*, that is by osier beds or fascine mattresses; or the current is kept away by groynes, also of fascine work. When all these precautions are of no avail, a new dyke is laid farther back, called an *inlaagdijk*. This was, however, prohibited in old times, and the Count Floris V. of Holland ordained, in 1266, that if the old dyke could not be maintained another should always be laid in front, and not behind it. In less important cases, where no great depths are found, and for strengthening landings and river quays, the fagots are built up like a wall, and then called *pakwerk*. Where the slope has to be defended from an overflow—a weir for instance, or from surf—the brushwood is spread over it, kept down by low osier wattle work, called *tuinen*, and covered by brick, ballast, gravel, or quarry refuse; this is called *beslagwerk*. Similar constructions are also used for improvements in the river bed. Mr. T. C. Watson, M. Inst. C.E., has, in an interesting Paper, given a full description of fascine works in Holland.[1]

The foreshores are also defended from occasional spates by low dykes, *summerkade*, which are covered during the higher floods, and allow the stream to extend over such foreshores or *waarden*. The bandykes are usually from 4½ to 5½ mètres wide at the top,

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xli., p. 158.

with slopes of $2\frac{1}{2}$ or 2 to 1 and 2 or $1\frac{1}{2}$ to 1 outside and inside respectively. Except in very few cases the dykes on the rivers are faced with fascine works; the sea dykes, however, are more and more being overlaid with heavy stone pitching, since in 1730 the *teredo navalis* was noticed in the seaweed, fagots, and timber.

Notwithstanding the care taken of these dykes, inundations have always been frequent; they became more destructive as the dykes increased in height, and as the area left for the spates diminished by polders encroaching on the rivers. Where a breach occurs a deep hole is usually made in the ground by the water. Pools, or *wiels*, are everywhere numerous along the river dykes, and show the great frequency of these calamities.

Before taking a rapid glance at what has been done to obtain, as far as possible, immunity from danger and to improve the rivers, the boon and the bane of the Netherlands, a short description is necessary of their course and of their characteristic features. In the following statement all heights refer to the datum of the Amsterdam Peil, or the former mean high water at Amsterdam, about equal to mean sea level in the North Sea and Zuiderzee.

The bandykes are shown in thick black lines on the accompanying maps (Plates 10, 11, and 12).

General Description.

The Rhine receives a great number of tributaries, of which the Aar, the Neckar, the Main, the Moselle, the Ruhr, and the Lippe are the principal. Below Emmerick, in Rhenish Prussia, the river reaches the delta with an average discharge of 2,500 cubic mètres per second in the summer, and 10,000 cubic mètres per second in the winter and spring.[1] Its surface width is 480 mètres in summer, and 2,550 mètres in winter, and the river drains an area of about 4,000 geographical square miles.

Above Emmerick this river has flowed almost exclusively between high banks and in a natural channel, for ages, without important changes. In the lower reaches, however, the stream in many branches meanders to the sea through alluvial plains, and must be confined to a constant bed, mainly by dykes and embankments. About 19 kilomètres below Emmerick the river divides near the village of Pannerden into two branches: 1st, the Waal, taking two-thirds of the total volume, bending south and afterwards west,

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[1] February 8th, 1862, surface at Emmerick at 17·38 mètres + A.P., 10,403 cubic mètres per second. Waal at Hulhuizen 6,936 cubic mètres.

with a discharge of 1,600 cubic mètres per second in summer and 7,000 cubic mètres per second during flood; and 2nd, the Lower Rhine, flowing north and west, receiving the remainder. This proportion, of two-thirds and one-third to the Waal and Lower Rhine respectively, is maintained as far as possible by a groyne or jetty pointing up-stream from the island between the two branches, cleaving the river as it were, and by bridling and profile works on the banks.

The Waal after two bends passes the ancient city of Nijmegen, situated on a spur from the Cleve hills, on the left bank, and Tiel on the right, and near St. Andries approaches the Meuse. Here, between the villages of Dreumel and Rossum, a narrow neck of land, about 1 kilomètre wide and 6 kilomètres long, separates the two rivers, which being left undyked allows the Waal water during high floods to flow over into the Meuse. A short canal with locks establishes communication for shipping. Three channels which formerly existed have been closed one after the other, the last in 1856. Flowing on past the city of Bommel on the left hand, the Waal receives the Meuse near Woudrichem, also on the left bank, with a volume of 200 cubic mètres per second in summer, and 4,000 cubic mètres per second in winter, and is thence called the Merwede. Passing Gorinchem, on the right bank, the Old Merwede continues its course to Dordrecht, but the greatest volume of water passes through the newly-formed channel in a southerly direction to the Hollandsch Diep estuary. The mouth of this new branch near Deeneplaat is 600 mètres wide in the summer bed, with 200 mètres foreshore on each side. The distance from Emmerick to the Deeneplaat is 124·8 kilomètres; the fall in that distance is about 12 mètres, or about 1 in 10,000, in summer, and 17·5 mètres, or 1 in 7,000, during floods. Except at Nijmegen and near St. Andries the river is embanked on both sides, and the tide runs up to Bommel.

The Lower Rhine, about 6 kilomètres below its separation from the Waal, receives, near Kandia, the discharge from an old side branch, which during floods takes water from the Upper Rhine over a weir near Lobith on the north bank, and 4 kilomètres below Kandia, near Westervoort, gives a third of its total volume to the Geldersche Yssel, on the right bank. The Lower Rhine passes Arnhem, on the right bank on high ground, and along the foot of the Veluwe hills to Wageningen, where the dyke recommences and is carried as far as Grebbe, and about 7 kilomètres lower down. Thence past Rhenen to Amerongen the stream is bounded on the right bank by high ground. At Amerongen the Lower Rhine is called the Leck, and

passes the ancient city of Wijk bij Duurstede on the right, Culenborg and Vianen on the left, and Schoonhoven on the right again, to Krimpen, where it receives the Hollandsche Yssel, an old side branch. Here the Leck unites with the Noord, which communicates with the Old Merwede at Dordrecht, taking the name of New Meuse, passes the towns of Rotterdam, Schiedam, Vlaardingen (where it communicates with the Old Meuse through the Botlek to the south), and Maassluis, and through the new channel of the Hook of Holland, to the North Sea. The total distance from this spot to the separation from the Waal near Pannerden is 166 kilomètres; the fall in summer is about 10 mètres, or 1 in 16,600; and during freshets about 15 mètres, or 1 in 11,000. Except near Arnhem and Rhenen the river is banked on both sides; on the north, the ancient and important Grebbe dyke and the North Leck dykes defend the richest parts of the country, and many deep polders in South Holland. The island between the Waal and Lower Rhine branches is divided into five principal "waterschappen," or confederations of polders: the Upper and Lower Betuwe, the Tielerwaard, the Alblasserwaard, and Vijfheerenlanden; of these the two last lie very low, viz.: from 1·20 mètre to 2 mètres below A.P. in some parts. This island is partly drained by the Linge brook, which runs nearly east and west through it, and discharges into the Merwede at Gorinchem, and through a deviating canal, made in 1819, thence to Steenenhoek, 8 kilomètres further west. From near Culenborg on the Leck to Gorinchem, cross embankments, known as the Dief dyke and the North Linge dyke, partly defend the Vijfheerenlanden and Alblasserwaard from inundation and from breaches in the Veluwe dykes above it, and lead the flood water to the Merwede, through locks and over weirs in the river dykes near Dalem between Gorinchem and Vuren.

The Hollandsche Yssel was in old times a side channel of the Leck, and flowed out of it below Vreeswijk opposite Vianen; now the only communication is through a culvert and sluice. It bends from thence to the north, past the town of Gouda, and is locked above that place. Lower down the river is tidal; at Krimpen it joins the New Meuse, enclosing, with the Leck, the waterschappen of the Lopickerwaard and Krimpenerwaard, and receives the drainage of a large tract of South Holland. The waterschap of Rhineland discharges partly into it at Gouda, with a pumping engine below the lock, of 250 HP.

The Geldersche Yssel branches off from the Lower Rhine with a long curve at Westervoort, flows with many bends in a northerly direction, successively past the towns of Doesborgh, where it receives

the Old Yssel, Zutphen, where the Berkel brook falls into it, and Deventer, all on the right bank, and past Hattem and Kampen on the left bank. Opposite Hattem, near Katerveer, a canal communicates with the town moats of the city of Zwolle, and the creek of the Zwarte water, which runs past Genemuiden, and between jetties nearly 6 kilomètres long, into the Zuiderzee at Kraggenburg. Below Kampen the Yssel flows through two mouths, the Ganzendiep to the right, and the Keteldiep, which has been much improved of late, into the Zuiderzee. The total distance along the fairway from its separation from the Lower Rhine to the Ketelmouth is 127·8 kilomètres; its fall in that distance is 9·15 mètres when the river is in ordinary condition or 1 in 14,000, and 13·90 mètres during floods or 1 in 9,000, in round numbers.

The dykes of the Geldersche Yssel are not continuous, the river being partly confined between high banks. At the upper end the east bandyke of the Lijmers district constitutes its right bank as far as Doesborgh. Between Lathum and Bingerden a lowered dyke-length allows inundation water coming from breaches in the North Rhine banks, to discharge at this spot into the Yssel. The Old Yssel, besides draining the high ground to the east, also intercepts this flood water, bringing it past Doesborgh on the main river. From Bingerden to beyond Deventer, high ground renders a bandyke unnecessary, thence downward bandykes reach to Kampen. The left bank is dyked all the way from above Zutphen to the sea, except for a short length above Hattem, skirting the high ground of the Veluwe.

The Meuse has its source in the Vosges, and, flowing in a northerly direction, passes the towns of Commercy, Verdun, Sedan, Dinant, Namur, Liège, Maastricht, and Venlo, and leaves the higher moorlands near the village of Mook, above Grave, to enter the delta, with an estimated volume of 170 cubic mètres per second in summer, and of 3,800 cubic mètres per second in winter, being the drainage of 860 square geographical miles. Passing Ravenstein to St. Andries, where it receives the flood water from the Waal over the undyked Heerewaarden lands, and communicating with that river through a short canal and double lock, it reaches Crèvecœur, where the Dieze brook discharges into it through a lock; then past Heusden, it joins the Waal near Woudrichem, opposite and above Gorinchem. The direct distance from Grave to Woudrichem is about 50 kilomètres, the length of the fairway 95 kilomètres, and the fall in that length about 4 mètres, or 1 in 23,750. The river is dyked on both sides, except on the left bank

in two places—between Cuijk and Grave, near St. Andries, and near Bokhoven—where, in winter, flood water is allowed to overflow the low-lying polders of North Brabant, to discharge past Bois-le-Duc, and across the weir at Baardwijck, the Little Meuse, and the Amer, to the Hollandsch Diep.

The estuaries are numerous, and intersected by cross channels forming numerous islands and shoals.

The Hollandsch Diep, after passing under the railway bridge at Moerdijk,[1] divides near Willemstad, about 18 kilomètres west of the Deeneplaat, into two wide arms communicating directly with the sea—one bending south and then west, with the names consecutively of Krammer, Volkerak, and Grevelingen, reaches the North Sea beyond Brouwershaven on the south shore, on the island of Schouwen; the other arm, continuing in a north-westerly direction, joins the sea past the harbour of Hellevoet, under the names of Haringvliet and Noorderdiep. The two arms enclose the islands of Goerêe and Overflakkee. From the Merwede at Dordrecht to the Hollandsch Diep, near Moerdijk, the Dordtschekill, though narrow, affords a good navigable channel for large ships to Brouwershaven, with a minimum depth of 4 mètres at low tide. The Old Meuse runs westerly, forming with the Haringvliet the islands of Beijerland, Putten en Voorne, and with the New Meuse and Noord the island of Ysselmonde. Receiving some of the water from the New Meuse through the Botlek, forming with it Rozenburg island, and widening out, it reaches the sea beyond Brielle. The coast bends south-west and north-east. Before high water the current sets from the south-west, returning in that direction with the fall of the tide. The mouths of the estuaries on the coast all bend to the south-west, opening against the rising tide, and discharging parallel to the ebb current. The islands are all dyked; their surface is generally above low-water level, and they are mostly drained by gravitation. Only on their western edges, nearest the sea, do sand-downs exist, forming a continuation of those on the other parts of the eastern coast of the North Sea. A canal through the island of Voorne, from Hellevoet to the Old Meuse, at Nieuwesluis, enables vessels of 5 mètres draught to reach Rotterdam from the sea by the Goerêe channel through the Botlek and the Old Meuse. The rise and fall of the tides, and direction and velocity of the currents in these estuaries, are very irregular, particularly so in the cross channels.

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[1] Of fourteen spans of 100 mètres and two of 16 mètres, or about 1 mile in length.

Such is a general outline of the present course of the Rhine and Meuse in the Netherlands. They were naturally subject to many changes in bygone ages. It is supposed that the coast line advanced much farther west into the German Ocean before the Cimbric flood in 110 B.C., when the sea forced a passage through the present Straits of Dover, and its mean level was permanently raised, swamping large tracts of land, which still exist as sandbanks in the North Sea.

The earliest geographical information about the delta of the Rhine is obtained from the Romans, and must be inferred from their description of battles and campaigns in those parts. It is probable that in those days a branch left the Rhine just below the Elten hills, near Emmerick, and flowed northwards through marshes and fens. The Roman commander, Drusus Germanicus, first made this branch navigable, and embanked parts of it. The principal channel of the Rhine flowed to Wijk bij Duurstede, and thence to the north, with many branches, one past Leyden, another through the Zuiderzee, which was only an inland mere, and, through a mouth called Flevum, past the Helder. Below Wageningen some water was also discharged to the north, and the Roman Domitius Corbulus cut a passage from below Wijk to the westward, which is the present Leck. This joined a wide gulf, the *os immensus* of Tacitus, now divided into several estuaries. No islands were mentioned as existing in it. The Waal and Meuse had a common outfall into this gulf. The towns of Nijmegen (Oppidem Batavorum), Wijk (Dorestad), and Utrecht (Nifterlake) were commercial towns at that time, and continued to be so till the reign of Charlemagne. By the sixth and seventh centuries many embankments had been formed, and tracts of land poldered, as the population increased. In the thirteenth century a large part of the country had been so reclaimed, as shown by several laws and charters of those days. The Grebbe dyke was already an important work; and in 1233 and 1234 the Count of Holland caused the North Leck dyke, from Amerongen to Schoonhoven, to be laid down. A law was made against digging for peat in places dangerous to existing dykes. No important changes seem to have occurred till the great flood of 1421, which swamped the whole country, and destroyed the South Hollandsche Waard between Dordrecht and Gorinchem. After this calamity the Waal and Meuse, which had before followed the bed of the present Merwede, pursued a shorter road to the sea across the submerged land; and the Waal, obtaining a better fall than that of the Lower Rhine, soon became the principal mouth, drawing more water than the others.

Nothing was done to counteract the altered condition, or to make the best of it, owing to civil wars and disturbances. Consequently, when the new Waal mouth began to shoal, and islands were warping up in it, the polders near Gorinchem, the Tielerwaard, and Alblasserwaard, were endangered by the raised river surface, which was, however, favourable to the shipping interest; and quarrels arose about this, as also about the Lower Rhine and Leck, so that nothing was done. At last a great inundation, on the 11th of January, 1624, swamped about 170,000 hectares of land, principally in South Holland, and brought the inhabitants to their senses.

The States-General took the matter in hand; but it was not till 1696 that the engineer Passavant reported to them on the Lower Rhine and Yssel branches. He found the Yssel in its upper reaches nowhere navigable; and the Lower Rhine and Leck, as far down as below Schoonhoven, fordable in many places, an invading French army having easily crossed the Rhine without boats near Lobith in 1672. The Waal took at that time nearly the whole volume of water from the Upper Rhine, leaving only a twenty-fourth to the other branches in summer; while in winter the undefended river banks and irregular and curving channels permitted any excess of water to flow down the Rhine. He proposed to discharge the Upper Rhine, over a weir in the north bank, near Zevenaar, into the Geldersche Yssel, to relieve the other branches. This plan, though often considered, was never executed. In 1701 a channel was begun for straightening the upper part of the Lower Rhine near Pannerden. It was finished in 1706, and gave much satisfaction, till, in 1740, a breach in the north bank below Emmerick threw a large volume of water into an old abandoned Rhine bed, and so into the Lower Rhine, again discharging into that river too large a proportion of water. Some works executed to improve these reaches were of no avail; at last the engineer Brunings, in 1770, was empowered to bring this vexed question to a conclusion. On his proposition a number of works were carried out between 1771 to 1776, which have remained almost unaltered. The bandykes on both sides were raised and strengthened, the old bed of the Rhine near Lobith was shut off by a dam, and a new channel was cut through two bends in the Upper Rhine below Emmerick, called the Bijlandsche canal. A groyne was also run out, pointing up stream, from the separation point of the Lower Rhine and Waal, so as to ensure to the Lower Rhine a permanent share of one-third of the total volume of the Upper Rhine, the rest of the water going to the Waal. The same system was put into practice at the division

between the Lower Rhine and Yssel, which last river received a new intake a little above the old one, and one-third of the total volume of water of the Pannerdsche canal. All these works were protected with "bleeslagen" and groynes. The weir near Lobith was the weak point in the system, but it had to be made on account of the polders above. It was decided at that time that the top was to be raised no higher than + 11 mètres A.P., but it has been since raised to + 13·91 mètres A.P. To counteract partly the bad effect of this side discharge, a portion of the bandyke of the Lijmers, near Oud Levenaar, was, in 1809, lowered to allow some of the water to escape across these lands to the Yssel at Bingerden. It has been of use twice only—once in 1820, and once in 1855—and was after this latter date raised again to its full height.

A bend on the Waal was also cut through at Bimmen, above Nijmegen, in 1654, and two bends were similarly dealt with at Waardenburg, near Bommel, in 1655 and 1680, by which that stream was straightened.

On the Lower Rhine about that time some improvements to deepen the fairway were also carried out at Malburgen, and in several places on the Leck after 1770.

The overflow from the Meuse, near Cuijk and Grave, existing since the fourteenth century, when the bandykes lower down had been united and continued, was regulated in 1766; and the weir at Baardwijk was lengthened in 1795, and again in 1812, when it was improved and strengthened.

So far the amended water division at the head of the delta had given good results, and the condition of the river beds was better than in the seventeenth century; but, on the whole, the want of system in carrying out the different works, and the numerous conflicting interests and local influences, led to slow progress being made. In 1800 the engineer Brunings proposed a number of improvements, but the disturbed times did not allow of much being done till 1815. The inundation of 1820, which flooded nearly the whole of the low grounds and polders, forcibly directed public attention to the subject.

A Royal Commission was appointed in 1821, which presented to the King a voluminous report on the state of the rivers, and advised many and very costly works, besides critically considering other propositions.

The commissioners were of opinion that during the preceding centuries the river beds had been much raised; that floods, too, were of late years more frequent, and rose higher, than before,

owing to a change of climate, cultivation, and improvements of the upper rivers. A proposition to dredge the river beds to the necessary depths was found impracticable, as it was calculated that to gain 1 mètre in depth about 200,000,000 tons of material would have to be removed, at an estimated cost exceeding 100,000,000 florins.

The German hydrographer Wiebeking advised that the bandykes should be raised and strengthened, and the fairway straightened. This was not considered feasible, as in many places the subsoil was unable to carry a heavier embankment, and it was next to impossible to clear away all the villages and dwellings on and near the dykes to make room for structures of increased dimensions.

Mr. Luitjes urged that the bandykes should be lowered so as to allow the swollen rivers to overflow, and thought that in this way the silt would, like that of the Nile, enrich the land, and in course of time raise the surface. He, however, excepted from this system such low polders as had no natural drainage, and would, therefore, remain flooded all the year round unless powerful artificial draining could be resorted to. Against this idea it was averred that the fructifying properties would be uncertain, as the silt is not precipitated equally over a large surface, and the river often carries sand and gravel instead, and would be continually varying its course, which could be hardly prevented, and would often not be discovered till too late.

The Government engineer Goudriaan suggested that a great number of overflows or weirs should be made in the dykes at convenient places, so as to allow flood water to leave the river, and to lead this water between dams across the land, through so-called "green rivers," to spots where it could be got rid of. However, large tracts of land would have been almost permanently under water, and this scheme was open to the same objections as that of Mr. Luitjes.

General Kraayenhoff proposed to form new rivers by excavation, through the lowest districts, and in as direct a line as possible to the sea. In outline his idea was to lead the Rhine through a new channel from near Lobith to Doesborgh, thence to straighten the Yssel to Deventer, and from thence to give it a single and capacious outfall into the Zuiderzee; to canalise the Lower Rhine and Leck from Pannerden to Krimpen, dividing this branch into eight levels by means of locks; to close all communication between the Waal and the Meuse, and to give this last river a separate outfall, by reopening the ancient mouth passing by Geertruidenberg; and to close the creeks and channels of the Biesbosch, so as to lead all

the water of the Waal through the Merwede to Dordrecht. These gigantic schemes were open to the objection of their great costliness (60,000,000 florins), and that though the low polders on both sides of the Leck would in future be free from inundations, the whole of Holland would in dry summers be without fresh water. The danger of icedams on the Waal, and of floods and inundations in the Alblasserwaard and other low polders, would not be obviated, and it was thought North Brabant would not be sufficiently relieved from periodical floods.

The Royal Commission, after taking evidence, suggested a series of improvements, adopting some of the propositions mentioned. They favoured:

1st. An overflow between leading dams from Lobith, through the Old Rhine bed and past Zevenaar, to Lathum above Doesborgh, cutting through a number of sharp bends in the Yssel, clearing the foreshores on both sides of obstructions, and giving it a new and roomy outfall past Kampen to the Zuiderzee.

2nd. A side discharge, or "green river," from Weurt, below Nijmegen on the Waal, to Appeltern on the Meuse, and across this river and the North Brabant polders to Baardwijck.

3rd. A discharge from the Leck by means of sluices in the Grebbedyke below Wageningen, and past Amersfoort to the Zuiderzee.

4th. The strengthening of the North Leck dykes from Amerongen to Schoonhoven, raising them higher than those opposite the river, and to allow floods to flow across the Betuwe, above the Dief dyke, and across the Linge dykes into the Merwede, at Dalem, near Gorinchem.

5th. A similar arrangement for discharging flood water during dangerous spates from the Merwede across the Altena polders to the Hollandsch Diep, near Geertruidenberg.

6th. The formation of a new channel across the Biesbosch.

The Commission also recommended that the law of 1806, for the better superintendence and maintenance of the rivers, should be strictly enforced; and they estimated the total cost of their propositions at 18,250,000 florins.

Against the views expressed by this Royal Commission it was contended that, according to observations, the bed of the rivers had not been raised during the last eighty years, and that floods did not rise higher than before. The proposed green rivers, and the lowering of the Betuwe dykes, were much deprecated, and the sum to be expended was thought excessive. Nothing was done, and a second Royal Commission was appointed in 1828. Wars and troubles

intervened, and the report was not published before 1849. Except as to the overflow of Weurt and of Altena, which were thought unnecessary, the second commission seconded the propositions of their predecessors, but reduced their estimate to 12,000,000 florins.

In the mean time some improvements had been carried out; the Beersche Meuse, or overflow from Grave to Baardwijck, had been cleared, so that flood water was got rid of in a shorter time than previously, and the North Leck dykes had been brought into a better state. At last, in 1850, a valuable report was made on the subject by two eminent Government engineers, the late Messrs. Ferrand and Van der Kun, containing numerous suggestions; which have all been followed, and that able advice still directs the system of improvements. They proposed that the rivers should be brought everywhere as far as possible to a regular channel and definite widths, that narrow places should be widened, and wide side-bays filled up, and the stream led into a regular channel by groynes and parallel dams.

They also recommended:

1st. The making of a new mouth for the Waal and Merwede across the Biesbosch and Bergsche Veld, and the improvement of the Merwede to Dordrecht by dredging and groyning.

2nd. To regulate the overflow and channel near St. Andries.

3rd. To regulate the Leck below Culenborg by groynes.

4th. To strengthen some weak parts in the Leck dykes, and to cut off a sharp bend in the Leck above Wijck, the so-called Roodvoet.

5th. To raise refuge mounds in districts liable to inundation, particularly the Betuwe above the Dief dyke, which it might in some cases be necessary to flood in order to save the low-lying polders north of the Leck; and

6th. To improve the Yssel.

They were of opinion that with a yearly expenditure of 200,000 florins these works might be brought to a close within a reasonable time. On their advice also, the staff of the Netherlands' Waterstaat was much strengthened; and it is mainly to the able and untiring efforts of this eminent corps of Government engineers, and to the soundness of the views expressed by Ferrand and Van der Kun, as proved by the experience of the last twenty-eight years, that the country owes its immunity from dangers and calamities like those of the previous period.

It may be of interest to notice the river work in the Netherlands during the last quarter of a century, and the results obtained, without going into minute details.

The Merwede.

The key of the situation was the Bergsche Veld, or Bieschbosch. How to make a roomy waterway through this group of islands, at a moderate cost, was the first problem to be solved.

Anterior to 1421 the Bergsche Veld formed part of an island called the Great South Holland Waard, between the different branches and estuaries of the Waal and Meuse, covering an area of about 44,000 hectares. Its boundaries were, on the north the Merwede, on the west the inlets of the North Sea called the Meeren, on the south the high moorlands of Brabant, and on the east the Meuse. Before 870 another branch of the Meuse flowed through the island, but had silted up, and had then been dammed off and poldered. The soil consisted partly of clay and river deposit, and partly (this principally on the south side) of low peat bogs. The surface cannot have been lower than low-water mark, or about A.P., as the whole island being enclosed in one ring dyke depended for drainage on the ebb. In 1421 no mechanical means were known for raising water; only sluices existed, and there is evidence of many locks having been built in Holland before 1315.

The peat fens, however, were probably a good deal lower, having been dug for turf, as proved by documents of 1313, 1403, and 1409, in which the Counts of Holland granted licenses thereto; and of 1382 and 1404, by which it was forbidden to excavate too near the dykes, for fear of damage. These dykes certainly existed in 1374, and probably long before, as in that and following years contracts were made between different landowners to assist each other with men, ships, and materials, in case of breaches. These contracts also refer to inundations having previously flooded the whole island, the dykes having been carried away, and much mischief done.

At midnight on the 18th of November, 1421, during a heavy north-west gale and spring tide, the dykes succumbed in two places—one on the north, on the Waal, still called the Oude Wiel; the other in the sea dyke near the Meeren, on the south side, which had been strengthened about ten years before. Thus the sea water was let in, and during that single night the site of a well-cultivated and prosperous island was turned into a lake, drowning more than 100,000 inhabitants, and destroying seventy-two villages, of which thirty seven were lost for ever.

The Waal and Meuse cut a deep channel through this submerged land to the Meeren and the sea. Attempts to close these breaches,

and to re-drain the flooded land, were made in vain during the following years; but soon after the calamity the eastern and western parts—the land near Heusden and Strijen, being probably the highest, and therefore least submerged—formed into separate polders. In 1620 other tracts were reclaimed, and in that year the island of Dordrecht was partly embanked again. Other portions also again became shoal and dry in patches, forming low, reedy islands; this occurred, however, but slowly, and principally on the north side, near the Merwede bank, near Dordrecht, and north of the island.

This new channel having shortened the course of the Rhine to the sea by one-third, the Waal began to draw more water than the Lower Rhine, and soon became the principal branch, to the great detriment of the mercantile towns on the Lower Rhine and Leck, though part of the Waal water seems still to have flowed through the old bed to Dordrecht, and through the New Meuse past Rotterdam to Brielle.

For about a century and a half the situation remained unaltered. In 1565 the inhabitants of Dordrecht and Rotterdam found the waterways deteriorating; and, as in the mean time more islands had been formed, they wanted to close the creeks between them, to direct a greater volume of water along the Merwede and the New Meuse. This was partly done, with the approval of the Regent, Margaret of Parma; but the inhabitants of Gorinchem and of the Alblasserwaard and Altena polders objected, as the closing of these creeks would have raised the surface of the river, and endangered the dykes. In consequence, they again destroyed what the Dordrecht and Rotterdam people had done, and maintained an armed vessel in the Merwede to prevent anything of this kind being carried out in future. As more land became dry, it was leased, on condition of planting it with willows and reeds, to augment the silting-up; in consequence of which, about 1725, the water only flowed through the Bergsche Veld in numerous narrow creeks, which still drew away so much water that the fairways to the west were incommoded. The merchants of Rotterdam complained that the bar at Brielle was so shoal that where, in 1700, the largest men-of-war could float, there was then only about 4 feet depth of water at low tides. An ineffectual attempt was made in 1726 to dam these creeks on the Bergsche Veld, and another trial failed in 1738. In the former year it had been proposed to shut off all the creeks by a low embankment, so as to allow water to escape over it when the water rose above a certain level; and this had been partially constructed, when it

was destroyed by ice and high water during the following winter.

A similar accident happened to a dam across the Bassekill, made in 1752, and to the other creeks in 1770. In 1805 and 1806 the attempt succeeded, but, not being properly maintained, the embankment had not the expected effect, and was soon ruined.

Ultimately the inspectors of the Waterstaat, Ferrand and Van der Kun, proposed to combine the two interests, improving the fairway to Dordrecht and Rotterdam through the Merwede, and giving a free discharge to the Waal, which below Woudrichem has a maximum volume of 9,600 cubic mètres if the Rhine and Meuse are simultaneously at their highest level, namely, the Waal discharging 7,000 cubic mètres, and the Meuse 2,600 cubic mètres, per second. This was to be effected by clearing the course of the old river of banks and shoals, and by forming a single channel through the Bergsche Veld wide enough to carry the whole of the water of the Waal in case of need, but only about two-thirds of it in summer, the other third to be given to the Merwede and the Leck through the Noord.

This judicious advice was followed, and in 1851 the work was started. The system pursued was, first, to throw out groynes from the up-river bank at the entrance of the creeks, abstracting the water from the Merwede; the groynes, pointing into the old river and down stream, turned the current off the creeks, and led it back to the Merwede. This river, and the Noord, were at the same time regulated by parallel dams and groynes, to obtain a better scour, and some shoals were dredged away. It was decided to form the new channel through the most important creek, called the Westkil, leaving the Merwede at an angle of about 45° in a south-west direction, then curving west, south, and south-west again, and falling into the Hollandsch Diep through the Deeneplaat. It was to be 400 mètres wide, 3·5 mètres deep below A.P. at the upper, and 4·4 mètres below A.P. at the lower end, with a foreshore on each side of 300 mètres, and a length along the centre line of 17·750 kilomètres. The width was afterwards increased to 500 mètres at the upper end, and 600 mètres at the mouth.

In 1852 low fascine dams, or sills, were laid at the mouth of the creeks along the Merwede, and head dams made at the inflow of the Westkil, leaving the proposed opening for the new channels. At the same time the higher parts of the islands, mostly near the Merwede, and what remained of the old dykes and dams of former works, were lowered to 1 mètre above summer level, and the earth was used for strengthening the dams in the creeks, so as to allow

the Waal to discharge over the whole Bergsche Veld when high, diminishing the current in the creeks and removing the pressure on the dykes of the Alblasserwaard and Altena polders. In 1853 the closing dams were laid down in a number of less important creeks, and those in the Bakkerskil and Steurgat were raised higher, and strengthened with earth from the adjoining islands and from those in the new channel, which were excavated to low-water point. This work went on for some years, as also the strengthening of the adjoining dykes of the Anna Pauwlowna polder, and the island of Dordrecht. The new channel had to be carefully watched, encroachments outside its proper course prevented, and damage repaired in the closing dams. In consequence of the diminished waterway, the mean river level was heightened near Gorinchem. In 1858, at the mouth of the Steenenhoek canal, it was 0·43 mètre higher than in 1848, to some degree diminishing the drainage of an area of 70,000 hectares Linge polders; and a steam-engine of 125 HP., which was finished in 1864, was erected to assist the discharge. In 1859, the whole channel having been completed to low-water mark, a gullet was dug along the centre line on the Deeneplaat and other islands lying in the way at its lower end, and training dams were laid parallel to the centre line 1,000 mètres apart, which much assisted the scour. This increased so much, that in 1862 a steam dredger of 25 HP. was put on, and in 1863 another, but smaller one, of 12 HP.; two more dredgers were added in 1864, and again two in 1866. The mud was carried into the adjoining creeks by ten iron scows and two 20 HP. tugs. As the capacity of the new channel increased, and the fairway in the old rivers improved, dykes were laid along the south bank of the Old Merwede, first only with their formation level at + 1·70 mètre to + 2·40 mètres A.P., and the leading dykes extended to the lower end of the new channel. In these years considerable repairs were needed, particularly by the dams in the Bakkerskil and Steurkil, which, owing to their depth and a sandy or boggy subsoil, were severely damaged at nearly every high flood. The same was the case with the new leading dykes, which were not yet consolidated. In September 1861, of the 1,200 cubic mètres of water per second which passed Gorinchem (the river being at 1 mètre below mean summer level), 370 cubic mètres flowed through the Old Merwede, 640 cubic mètres into the new channel, and 196 cubic mètres through the Steurgat. The dam in this creek was again washed away in January 1862, and had to be relaid; but the new channel had obtained a depth below low-water mark of 2·50 mètres. At last, in 1864, the dams in the

Steurkil and Bakkerskil, and the dykes to the south of the Merwede on that side could be raised to a height of + 4 mètres A.P. In this year, of the whole volume of the undivided Merwede at mean river height, 42 per cent. flowed on to Dordrecht, and 58 per cent. passed down the new channel. In 1800, the old Merwede only carried to Dordrecht 9 per cent., and in 1822 only 18 per cent., the rest being absorbed by the creeks. The creeks having been filled in, closed, or silted up, locks and sluices had to be constructed for the drainage of the adjoining old lands, and for navigation. A lock, 40 mètres between the gate, 7 mètres wide, and the sill at − 1·50 mètre A.P., was built at the Bakengat; also one at the Helsloot, and another at the Kikvorschkil, 43 mètres long between the gates, 7·30 mètres wide, and the sill at − 2 mètres A.P.

In 1869 the minimum depth in the fairway of the new channel was 3 mètres at the upper, and 4 mètres at the lower end, and the channel was widened to 450 mètres at the Merwede inflow, 500 mètres midway near Dordrecht island, and 600 mètres on the Deeneplaat in the Hollandsch Diep. The groynes laid before the creek mouths were cleared away as the closing dams became trustworthy, the Merwede bank was then regulated by parallel works, and the river cleared of several islands and bars by dredging.

In 1871, steamers drawing 3·10 mètres of water could pass up the new channel, and traders from Rotterdam to the Meuse, Waal, and Upper Rhine adopted this new route, preferring it to the old one along the Merwede, which had a depth of only 2·40 mètres.

The mean water-level at Gorinchem had also fallen 0·32 mètre since 1856, indicating the benefit derived by the Waal from its new mouth. Dredging still went on, often under great difficulty from the snags and old trees imbedded at the depth of − 4 mètres A.P., which had been reached by this time. Great attention, too, had to be paid to the new works, and repairs went on incessantly. After 1867 it became possible to contract for the current maintenance, which had been previously impossible. In 1875 the new channel was practically completed, though the cost of repairs is still heavy and constitutes a large portion of the total expenditure.

All the work, except some locks and sluices, was fascine work, earth and boulders, no other material being resorted to. The dams below water were raised by consecutive layers of "sinkstukken," or fascine mattresses. The total quantity of soil dredged between 1862–1875 from the Merwede and the new channel, now called the New Merwede, was a little more than 5,800,000 cubic mètres, at

a total cost of 1,689,586 florins, or at about 0·333 florin per cubic mètre. The amount spent on these works from 1851 to 1875 was—

	florins.
For indemnities and expropriation	637,334
„ repairs and maintenance	1,804.323
And for new works proper.	5,020,841
Being a total of	7,462,498

WORKS ON THE UPPER RHINE AND WAAL.

After the inundations of the Zuid Hollandsche Waard, in 1421, the Waal gradually became the principal branch of the Rhine, carrying to the sea two-thirds of the total volume of water, and at times even more. On both sides of the river the surface of the polder land is considerably below flood level, except for a short distance on the left bank, at the ancient city of Nijmegen, where the stream cuts into a spur of the Cleve hills, on which the city is built. In preceding centuries many improvements had been effected by straightening and deepening the river, but these works being local, and without reference to a general plan, left much to be done. Ferrand and Van der Kun had indicated the proper course to be pursued, and proposed to regulate the widths of the river in the following manner:—

The summer bed to have a width of 400 mètres for the undivided Upper Rhine to Pannerden; of 360 mètres from the division to Bommel; of 360 mètres from Bommel, widening to 400 mètres at Loevesteijn; of 600 mètres from Loevesteijn for the united Waal and Meuse, called the Merwede, to the mouth of the new channel across the Bergsche Veld, which was to be 500 mètres wide; and the bandykes of the polders on each side, to be 100 mètres apart. Narrow parts were to be widened; wide reaches to be narrowed by groynes and parallel dams, and the current to be confined as much as possible to a single channel.

In 1851, a beginning was made with the new system. The Upper Rhine, between Lobith and Pannerden, had remained in a satisfactory state since the improvements of 1771. Here, in the period from 1851–1875, repairs only were necessary, and the dykes near Spijk were strengthened by fascines and groynes.

Before a definite plan was adopted, it was found advisable to settle the question of the St. Andries channel. Near this place the Waal and Meuse flow parallel to each other for a distance of 6 kilomètres, on an average only 600 mètres apart, separated by a low isthmus about + 6 mètres A.P. This isthmus had, in 1599, been

cut through for military purposes, and three channels existed by which much of the Waal was discharged into the Meuse. During floods in winter and spring, when the height of the Waal exceeded + 6·50 mètres A.P., the river flowed across the whole width of 6 kilomètres between Heerewaarden and Rossum. The three channels drawing too much water from the Waal, and this river shoaling, in 1728 two openings—one above Heerewaarden and one near Vuren—were closed; but the lower channel, near the fort of St. Andries, was allowed to remain for navigation. The channel having widened, and in 1830 having shown a tendency to discharge all the water of the Waal into the Meuse, an attempt was made in 1837 and 1838 to prevent it by laying down a groyne at the northern entrance, though without much effect on the fairway of the Waal. It was difficult to improve this reach below the channel, as, when the Meuse was the higher of the two rivers, water flowed into the Waal, and made the problem complex as long as the channel remained open. But it was thought imprudent to close the channel altogether before a better outlet had been given to the Waal across the Bergsche Veld, and in 1851 it was reduced again by another groyne. As the clearing on the Biesbosch proceeded, a commencement was made in 1853, by raising a fascine ring-dam westward of the channel, and laying down in it the concrete foundation for a lock, which was finished in 1855. The dimensions of the lock are: sill on the side of the Waal, 3 mètres below mean river level, or + 0·85 mètre A.P.; on the side of the Meuse, + 0·35 mètre A.P.; extreme width, 8 mètres, and length between the gates, 90·50 mètres; top of the walls, + 9·75 mètres A.P., and of the gates, + 7·75 mètres A.P. There are four pairs of gates, two in each direction, so as to lock either way. When the river rises above + 7 mètres A.P., the lock is closed by "schot-balks," piled in grooves in front of the gates. The lock is amply sufficient for the passage of the largest ships navigating the Meuse. Immediately after opening the lock for traffic, the old channel was closed, in March 1856, by a dam 350 mètres long between the lock and the old fort of St. Andries, advantage having been taken of a propitious moment in respect to the levels of the two rivers, and it was raised to a height of + 8·25 mètres A.P. The total cost of this work, with entrance passages on both sides, and closing the dam in the old channel, was 367,285 florins. The overflow across the grounds of Dreumel and Heerewaarden, between the west dyke of the Dreumel polder and the old St. Andries fort retained a width of about 3,500 mètres, with a minimum elevation of + 6·95 mètres A.P.; and

there is another width of about 1,130 mètres between the new lock and the Rossum dyke, which begins to be covered when the river is at + 6·60 mètres A.P., or about 2·54 mètres above mean level.

About the same time the dyke of the Erlecom polder, on the left bank above Nijmegen, gave much trouble. At this point the Waal impinges on the shore, and scours a pool of more than 10 mètres depth below mean river-level, with its deepest gullet parallel to, and only 20 to 40 mètres away from, the toe of the dyke. Frequent slips occurred; the dyke was breached repeatedly, and the polders behind it flooded. The fairway being so near, no groynes could be projected from the bank, and it was only possible to defend this section by strengthening the dyke, principally below water, by a "bleeslaag." Some work was done in 1851, but the proprietors of the polder not being financially able to go on with the work, the Government, in 1862, put down "sinkstuks" of 3,900 and 600 square mètres over a length of 150 mètres, 200 mètres of "beslag," and 600 tons of basalt ballast, for 13,600 florins; in 1863, 3,600 square mètres of "sinkstuks" were sunk on a length of 120 mètres, with 600 tons of basalt, for 9,800 florins; in 1864, 125 mètres by 30 mètres of "sinkstuk," with 600 tons of stone, for 9,488 florins; and 195 mètres by 30 mètres of "sinkstuk," with 600 tons of stone, for 10,500 florins, in 1865. The next year 340 mètres by 20 mètres of "sinkstuk" were deposited, with 800 tons of stone, and 340 tons of brick ballast, for 13,885 florins; in 1867, 230 mètres by 30 mètres of "sinkstuk," 600 tons of stone, and 230 tons of brick, for 9,946 florins. In 1868, further to defend this work, two perpendicular groynes were laid down from the foreshore of the Kekerdom polder, 142 mètres and 168 mètres in length, at distances of 920 mètres and 670 mètres above the upper end, at a cost of 13,900 florins. In 1869, 7,777 florins were spent in repairs, and a third groyne, 272 mètres long, was laid 220 mètres below the lower groyne of 1868, with a "sinkstuk" in continuation on the river bottom 75 mètres by 15 mètres wide, with 800 tons of basalt and 300 tons of brick, to prevent excessive scour along the head; this cost 12,786 florins. In 1870, a fourth groyne, 310 mètres long, was put down, 220 mètres below the groyne of 1869, and 50 mètres by 15 mètres of "sinkstuk" in continuation, with 750 tons of basalt, and 150 tons of brick, for 18,852 florins. In 1871, two groynes, 250 mètres and 500 mètres below the groyne of 1870, and 182 mètres and 100 mètres long respectively, and 1,200 square mètres of "sinkstuk," with 600 tons of ballast stone, and 400 tons of bricks, were deposited for 27,580 florins. All these groynes, with their ends 0·14 mètre above mean river-level,

rise 1 in 200 to their junction with the shore, and are 3 mètres wide on the top. In 1875 a further length of 100 mètres was protected with 600 square mètres and 1,000 square mètres of "sinkstuk," a "pakwerk" of 223 mètres, with 500 tons of stone, and 370 tons of brick ballast, for 7,900 florins. Up to 1875, 33,095 square mètres of "sinkstuk," 6,450 tons of stone ballast, and 1,790 tons of brick waste, had been used, forming a fascine defence 1,680 mètres long, for 148,407 florins, including five groynes of from 100 to 310 mètres long.

Below Erlecom, on the right bank, between that place and the city of Nijmegen, in the bend at Groenendaal, a cape projected into the river, forming a narrow. More than two centuries ago the river curved much further to the north than at present, but in 1654 the bend had been cut off by a channel 1,130 mètres long. The old bed had gradually silted up, and, assisted by willow plantations, and landings for a brickfield and kilns, the bank at last encroached on the river at its upper angle. Between the years 1857 and 1868 this obstruction was cleared away by lowering the surface to low-water level, and then intersecting it by ditches to help the scour, after having first closed the old bend with a summer quay, with its top about + 12·80 mètres A.P., or 1·30 mètre above the surrounding ground. Some dredging had to be resorted to for obtaining a depth of 3 mètres below mean water-level, as stiff clay, mixed with brick waste, was met with, resisting the action of the current. This work, including 460 mètres length of summer quay, with a "bleeslaag," parallel and 50 mètres in front of it, 500 mètres long, and indemnities to the amount of 23,594 florins for kilns and rather more than 3·80 hectares of ground, cost 73,867 florins.

The Waal between Pannerden and Nijmegen having three tortuous bends, it has been proposed to give it a new direction, either by cutting across the left bank from the Erlecom dyke to above Nijmegen, through the Ooij polder and the lands of Ubbergen, or by a new channel on the right bank to the north of the village of Lent, over the grounds of Elst. But the Ubbergen scheme would be too costly, necessitating a deep cutting through high ground, 4,000 mètres long; the other, though less expensive, would take the river away from the city of Nijmegen; and plans for the improvement of these reaches are for the present in abeyance.

At Nijmegen the river quay for some years showed signs of subsidence, partly caused by a deep pool being scoured in front, and partly by spring water from the higher ground behind. A

"bleeslaag" has been sunk in front along the quay wall, with a heavy covering of *pierre perdue* of basalt boulders, and holes have been drilled through the quay wall to drain the springs. Groynes are now being laid down in the bend above the city, to keep the current away from the wall. This work, which is still in progress, has so far been successful.

In addition to embankments for approaches to the railway bridges across the river below Nijmegen, made in 1876, and another similar work above the city of Bommel, made in 1865 and 1866, and the partial clearing away of small islands at Herwijnen, and near Ewijk, the works executed between 1851 and 1875, on the Upper Rhine and Waal, consisted of numerous groynes, parallel works, and dredging operations along the whole length of the river, which have already had a considerable influence on its carrying power and navigation, the minimum depth of water under mean river-level, between Emmerick and Gorinchem, being at present 3·05 mètres. These works are still being proceeded with. In many places the bandykes on both sides have been strengthened and raised, principally at the expense of the riverside owners; and several refuge mounds have been made in the lower districts, at Wamel, Kerkwijck, Brachem, Delwijnen, Heerewaarden, Apeltern, and Dreumel. These have an elevation on the top of about 1 mètre above highest known river-level.

The Meuse.

The Meuse is a tributary of the Waal. Its channel is tortuous and unequal; the direct distance between the towns of Grave and Woudrichem being about 56 kilomètres, whilst its length along the fairway exceeds 90 kilomètres, consisting of a great number of deep pools, divided by sills and shoals with a depth of only about 1·70 mètre, which render navigation impossible in dry seasons. The Meuse enters the delta near the village of Cuijk, 12 kilomètres above Grave, with a volume of water in summer of 170 cubic mètres per second. In winter and spring this volume is increased to 3,800 cubic mètres per second at Maastricht, and the river is then in a chronic state of overflowing, losing a large quantity of water over two lowered dyke lengths in the left bank below Cuijk, of 800 and 4,200 mètres in width respectively, with the tops at + 10·19 mètres A.P. This inundation water skirts the high ground of Ravenstein, and flows westwards across the Groenedijk (top at + 6·35 mètres A.P.) between this and the left Meuse dykes. The river near Lith and Alem receives water from the Waal across

the low grounds near Heerewaarden during floods in this branch of the Rhine; also from the accidental inundation water from the Meuse, and Waal, and Nijmegen polders, over the so-called Dreumel overflows, being two low lengths of dyke in the North Meuse bank (tops at + 7·49 mètres and + 6·95 mètres A.P.) at Alphen; which again raise its level, so that at Bokhoven, between Crêvecœur and Hedikhuijzen, it flows over its left dyke through two openings of 600 mètres each (tops at 3·80 and 4·10 mètres). This flood water flows south, joining that from Cuijk, and, turning westward, discharges into the low Lang-straat meadows, over a weir near Baardwijck, then past the town of Geertruidenberg and through the Amer creek into the Hollandsch Diep, thus inundating, nearly every year, a large part of the province of North Brabant. The main river flows on to meet the Waal at Woudrichem, where it discharges comparatively but little water into this branch, which is at such times brimfull. Usually the Waal is at a higher level than the Meuse near Heerewaarden and at St. Andries, particularly during floods, and in spring. Before the St. Andries channel was closed, the Meuse used sometimes to discharge water into the Waal in summer. To close this side discharge from the Waal at Heerewaarden would endanger the dykes of all the polders further down, and it constitutes the great difficulty in improving the Meuse. The fall in this river is much less than that in its neighbour, the mean river-level at Grave being + 4·09 mètres A.P., at Woudrichem + 1·45 mètre A.P., and at Nijmegen + 8·47 mètres A.P.; the fall from Nijmegen to Woudrichem is 7·02 mètres in about 65 kilomètres, and that from Grave to Woudrichem only 2·64 mètres in 90 kilomètres. The average fall on the Waal is 1 in 9,285, and that on the Meuse 1 in 34,190, or about a third of that in the Waal. Many plans have been suggested to remove the anomaly. In 1827 the ground was cleared of obstructions from Grave to the Dieze; locks were built on the right bank of the river, and the dyke on the left bank was lowered in several places so as to form an overflow to Baardwijck. This last weir was also widened at that time from 622 to 1,022 mètres. But even when covered with water to a depth of 1·15 mètre, it only discharges about 1,400 cubic mètres per second; whereas about 2,500 cubic mètres are calculated to flow into the Meuse across the overflow at Heerewaarden, with a fall of 0·10 mètre, and 2 mètres depth, as is not unusual during high water, and when obstructed by ice. The Meuse does not discharge all this excess of water at Woudrichem, where the current is sometimes very slight; and the remainder is temporarily stored

on the low ground near Bois-le-Duc, often flooding the district to a great depth.

Since 1851 much has been done, by groynes, parallel works, and dredging, to improve the summer bed of the river; the closing of the St. Andries channel by a lock has also had a good effect on the reaches below this point. Between 1858–1860 the mouth of the Dieze was also closed with a lock and improved, at a cost of 268,065 florins. This lock serves the double purpose of defending Bois-le-Duc from the Meuse water, and of assisting the navigation of the Dieze in dry seasons.

The only efficacious remedy against floods would be to reopen the old mouth of the Meuse which joined the Hollandsch Diep to the south of the Altena polders near Geertruidenberg, but which has since silted up. There is still a creek in that direction called the Little Meuse. General Kraayenhoff proposed in 1823 to open up the river from near Well, south of the town of Heusden, and to lead it into this creek; to widen the channel so that it should be capable of carrying all the water of the river, including the flood water; to enlarge the reaches to the same dimensions between St. Andries and the new mouth; and to close the present river to Woudrichem by a lock below the entrance to the proposed channel. The overflow at Bokhoven could then be shut off, and the water from the Beersche Meuse would cease to flow across the Dieze. The advantage of this plan was the better fall which it would give to the river. The mean low tide at Woudrichem is at present + 2 mètres A.P., that at Keizersveer, – 0·52 mètre A.P., giving a better fall of 2·52 mètres. High water at Woudrichem reaches + 2·22 mètres A.P., at Keizersveer + 1·32 mètre A.P., giving at high water an increased fall of 0·90 mètre. The new channel would have a length of only 21,000 mètres, whereas the length of the present course of the Meuse past Woudrichem and of the New Merwede to the sea is 45,000 mètres. By abstracting so much water from the Waal over the Heerewaard overflow, the flood level at Gorinchem would be lowered by about 0·40 to 0·50 mètre. At such a time the Meuse at St. Andries, reaching a level of + 8·77 mètres A.P., as on the 12th of February, 1871, and taking mean sea level at Keizersveer at + 0·40 mètre A.P., would give a fall of 1 in 3,570, as compared with 1 in 34,190 at present. This also would undoubtedly have a good influence on the Meuse above St. Andries, the tidal wave would then probably come up the river as far as Lith. The whole river would be so improved that the weirs at Cuijk might be closed. The inspectors of the Waterstaat, Van der Kun, Fijnje and Conrad, again strongly recommended this

scheme, and estimated the total cost at 4,000,000 florins in eight years; but the work has not yet been taken in hand.

Lower Rhine and Leck.

The Lower Rhine leaves the Upper Rhine at Pannerden, where it separates from the Waal, and takes, in theory, one-third of the volume of water. In the years immediately following their completion, the works proposed in 1771 seem to have answered very well; but latterly the quantity of water in the Lower Rhine has fallen off slightly, owing to a hard and ever-returning gravel bank in the mouth of the Pannerden canal. At mean river-level the Waal sometimes takes seven-ninths of the total volume instead of its proper share of six-ninths. When, however, the Rhine rises over + 13·50 mètres A.P. at Lobith, or 2·38 métres above mean river-level, the weir in the north bank in the mouth of the Old Rhine branch begins to be overflowed, and when the river is 3 mètres above mean level, the proper ratio is restored. In very high floods, like that of the 31st of January, 1861, with the river at 16·91 mètres at Lobith, or 5·80 mètres above mean level, the Lower Rhine receives too large a proportion of water. Such floods rarely last long, and the overflow is usually from 0·20 to 0·50 mètre in depth. The Old Rhine began to silt up soon after the opening of the Bijlandsche canal, but at the instance of the Cleve Government it was not embanked; and in 1745 only a weir was laid, 264 mètres long, which in 1771 was lengthened to 339 mètres, and it was decided that the height should not exceed 11·98 mètres. Formerly the water escaped to the Yssel across another weir in the north bank, near Oud Zevenaar, across the Lijmers district. Being of great inconvenience to this polder, the Lijmers weir was raised in 1851 to + 15·91 mètres A.P., and in 1860 still further to + 16·31 mètres A.P., or bandyke height; all the water entering at Lobith now flows back into the Lower Rhine near the village of Candia, below the Pannerdsche canal. Of the total volume the Yssel takes a little less than one-half, instead of one-third, although the works at Westervoort have been kept in good repair since their construction, in 1777. At low water, navigation is difficult for ships drawing more than 1·80 mètre.

In the period from 1851–1875 numerous groynes and parallel dams were laid down on the whole length of the river in order to obtain for it definite breadths. These breadths are 170 mètres from Pannerden to Westervoort; 150 mètres from Westervoort to Wijk bij Duurstede; from thence widening to 170 mètres at Vianen, where

the tide begins to be felt, and again to 200 mètres near Krimpen at the junction of the Lower Rhine with the Noord.

The principal improvements are: 1st, at Malburgen above Arnhem, where the fairway had been crooked and shallow; 2nd, in a bend above Wageningen, where the river was encroaching on the right bank; 3rd, near Jaarsveld, where a low island was united to the right bank, closing the intervening channel by a dam; 4th, the cutting through a troublesome double bend called the Roodvoet, above Wijk bij Duurstede, which was a source of danger to the dykes, by icedams settling in it. At this spot, in 1867, the summer quay enclosing this peninsula was set back on the right bank, and old groynes and other works in the way of the projected channel were removed. In 1868 a summer quay was laid on the left bank parallel with that on the right bank, and a ditch was excavated 30 mètres wide and 1·60 mètre below mean river-level. In the following year this ditch was widened from its central line to 90 mètres for the full length of the cutting, and to a depth of 1·60 mètre below mean river-level, leaving a dam of about 20 mètres wide at the higher end, with a centre cutting 1 mètre deeper. In 1870 the groynes and parallel works above and below the proposed channel were altered and prepared for the new direction of the current; and in the winter of 1870–1871, an ice-dam having formed in the old bend, the strip of ground at the upper end, having been excavated to a width of about 3 mètres, gave way to a head of 1·50 mètre between the river-levels above and below. The new channel was now speedily scoured wider by the current, and the old bend was closed, at first with low parallel dams, which were raised to 2 mètres above mean river-level in the next year. Some dredging was also necessary to clear away a stiff clay stratum above the sandy subsoil, which resisted the scour. In 1874 the left bank was further adjusted, to bring the channel to the normal width of 150 mètres; the groynes above and below the new channel were finished, and the banks on both sides were protected by fascine work. The depth of water in that year was from 4 to 5 mètres below mean river-level. The total cost of this work amounted to 395,761 florins, including 91,077 florins for land and compensation. Although the depth of water in the Nether Rhine has not augmented generally of late, some very shoal places have been improved, and the fairway has become much more regular as regards direction, width, and depth.

Besides these hydraulic works, the dykes, particularly those on the north bank, were raised and strengthened considerably. In the winter of 1855 the south bank was breached by high water and ice

in five places opposite Rhenen—three breaches occurred near Lienden, one at Ingen, and one at Maurik—and a great part of the Lower Betuwe island was flooded; the damage was repaired soon afterwards for 149,617 florins. The Nodijk dyke, between Wageningen and Grebbe, was breached in the same winter; and water ran over the North Leck dykes, at Amerongen, to a depth of 0·60 to 0·50 mètre for a length of 115 mètres; at Veertiggarden, 0·15 mètre deep for a length of 2,100 mètres; at Schalkwijck, 0·30 mètre deep for a length of 1,680 mètres; and near Culenborg, 0·20 mètre deep for 1,125 mètres. The dykes on the Lower Rhine and Leck are interrupted by sandy highlands from Arnhem to Wageningen, and again from Grebbe to near Amerongen; and instead of the usual earthen dykes, brick walls exist at Wijk bij Duurstede, Schoonhoven, and Lekkerkerk. After the calamities of 1855 these dykes were raised, the Nodijk at Wageningen to + 12·65 mètres A.P., and that at Grebbe to + 12 mètres A.P., the width at top being 5 mètres, the slopes outside being 3 to 1, and inside 2 to 1. The dykes from Amerongen to Schoonhoven were carried up to 1·40 mètre above the highest known flood-level, their width at top being 5 mètres, and their slopes 2 to 1; while at some places, where the subsoil was unsound, the slopes were increased to 3 to 1. The dykes of Krimpenerwaard were also raised and strengthened. In places liable to "kwelwater," or springs, ditches were sunk through the porous stratum down to a harder soil, and then filled with clay puddle. Where this could not conveniently be done, a second dyke was laid behind the existing bandyke, so as to confine the spring to its source, and all ditches and holes on the inside of the dykes, to some distance, were filled in. The sluices and locks in these dykes were also altered, to withstand the higher water. The dykes on the south bank of the island of Betuwe were raised and made level, and facilities given to discharge flood water from the polders towards the south into the Merwede. With this view, instead of the previously existing weirs at Dalem, above Gorinchen, two sluices were constructed in 1858 and 1859, with a united clear width of 36 mètres, and sill 2 mètres below the mean level of the Merwede. At Nieuwpoort the old town walls were raised to + 3 mètres A.P., so as to serve as a refuge in case of inundation; and the Diefdike,[1] a cross dyke defending the Alblasserwaard and Vijfheerenlanden polders against flood water from the higher ground to the east, was considerably strengthened. In this way the dangers to the low lands near Veenendaal and Amersfoort

[1] Made in the twelfth century.

from a breach in the Grebbe dyke, and to the deep South Holland polders from breaches in the North Leck dykes, have been much diminished. The Lower Rhine and Leck are now in a sound and thoroughly good condition, and events of unprecedented magnitude only are likely to damage the works.

The Geldersche Yssel.

The Geldersche Yssel is the smallest of the three mouths of the Rhine, and in theory only carries one-ninth of the total Upper Rhine water to the sea. This should be in summer and winter respectively 278 cubic mètres and 990 cubic mètres per second. At low-water level the quantity received by this river is much less; in 1809 it was only one twenty-fifth of the Upper Rhine, owing to deposits of sand at the junction with the Rhine at Westervoort. During floods a fair share is, however, obtained, and the mean river-level has even gradually risen since 1836, when the needle groyne at Pannerden underwent some repairs and slight alterations, to which this increase has been attributed. It is more probably due to the improvements in the fairway of the river, which are still actively going on. In the year 1865, for instance, sixty-six groynes, from 20 mètres to 56 mètres long, had been laid down in different spots along both banks.

The Yssel has a better fall than the two other branches, the total length along the fairway, from the junction at Westervoort to the mouth in the Zuiderzee being 126 kilomètres, with a fall at mean river-level of from + 8·99 mètres A.P. at Westervoort to + 0·44 mètre A.P. at the Zuiderzee, or 8·55 mètres, being equal to 0·068 mètre per kilomètre. Many plans have been brought forward to relieve the Rhine in this direction during floods and when ice floats down, particularly as the dykes are wide apart and high. In 1809 the north dyke of the Old Rhine, near the village of Oud-Zevenaar, had been lowered so as to give a passage to this river when flooded across the Lijmers district to the Yssel at Bingerden, where a similar lowering of the dyke had been effected. General Kraayenhoff and the two River Commissions had all advocated a cutting in this direction for a new channel. The weir at Oud-Zevenaar was totally breached and carried away by high water and ice in 1820. This ruined the whole Lijmers district. Again in 1850 the weir caused much inconvenience without being of much relief to the Rhine. Consequently it has now been raised to full bandyke height of + 16·31 mètres A.P. The Yssel receives three small rivers—at Doesborgh the Old Yssel, at Zutphen the

Berkel, and at Deventer the Schip Beek—which drain the high grounds to the east, and at Hattem the Grift, draining the Veluwe. None of these streams much increase the volume of the Yssel, except at times the Old Yssel, which intercepts the flood water when it breaches the North Rhine dyke near Emmerick or Rees, and discharges into the Yssel at Doesborgh, as happened on the 28th of February, 1838. After the closing of the Lijmers overflow the weir at Snippeling was raised. This had always been a point of contention. In ancient times the city of Deventer was situated on an island in the middle of the river, but the land to the east, becoming dry, had been poldered about the year 1300, by surrounding landowners, and a bank was laid down in 1358 between the city and the higher ground, as well as dykes to the east, to protect the polders of Zalland and the environs of Zwolle. This of course raised the level of the water during floods, to the inconvenience of the citizens of Deventer. The dyke was again raised in 1609, but was destroyed by the city in 1658; and though repeatedly repaired by the landowners, it was always breached by the drowned-out citizens, in order to obtain relief, during floods. In 1809 the maximum elevation had been fixed at + 6·60 mètres A.P., but in 1857 it was allowed to be raised to + 7·45 A.P., and in 1864 to + 9 mètres A.P., the main channel of the Yssel being considered by that time large enough for its volume of water. This result had been obtained by systematically regulating the width of the summer bed, bringing it to 100 mètres at Westervoort, 120 mètres at Deventer, 150 mètres at Katerveer, and 170 mètres from Kampen, to its mouth through the Keteldiep. The inspectors Ferrand and Van der Kun had also recommended, in 1850, that the five mouths of the Yssel should be reduced to one, with an outfall of sufficient capacity for the whole river. Several plans had been made on this subject, which also included the improvement of the waterway from the city of Zwolle to the sea. This ancient commercial city lies on the Zwarte Water, an old mouth of the Yssel, cut off from communication with the river by the gradual transformation of its north bank. In the fourteenth century a rudimentary canal had been made, to re-establish this navigation, which in 1809 was improved, widened, and deepened to − 1·80 mètre A.P. with two locks, one on the Yssel, with sills laid at 2·32 mètres A.P. on the Yssel, and one with the sill at − 2·05 mètres A.P. in the entrance near Zwolle, and a width of 6·04 mètres. For sea-going vessels this canal was too narrow, and they had to reach the sea by the Zwarte Water, between two jetties about 6,000 mètres long, ending in only 1·80 mètre depth of

water. Dredging and the construction of groynes had been going on for some time in this channel, but without much effect. In 1866 it was decided to deepen the canal of 1809 (the Willemsvaart) to − 2·10 mètres A.P., or by 0·40 mètre; to build a larger lock on the Yssel side; to deepen the Yssel to − 2·75 mètres A.P. from this point to near Katerveer; to replace the old bridge, erected in 1448, by a new bridge at Kampen, with an increased waterway; to close the Regter and Noorderdieps; and to lengthen the jetties at the mouth of the Keteldiep, from 2,950 to 3,750 mètres, so as to reach a depth of 2·50 mètres at their termination in the sea. All these works were commenced simultaneously in 1868, and successfully accomplished in 1873, by which a depth of more than 3 mètres of water has now been obtained from Zwolle to the sea, at mean low-water level. An overflow across the Dronthen polders, from above the city of Kampen to the west, still remains as a relief for high water and ice, and as a safeguard to the city.

The Ketelmouth had been chosen for its shortness—the Ganzendiep being about half as long again, and having two bends—and for its proximity to deep water and sheltered position, the island of Schokland, which lies to the north and north-west, breaking the force of the sea. Since 1873 the distance between the Ketel jetties has been increased from 70 to 100 mètres by relaying the northern dam 30 mètres farther outward. The lower reaches of the river and the fairway between the jetties need some dredging every year. The Ganzendiep remains as a shorter communication for small craft from Kampen to the polders lying to the north, and to the harbours on the Zuiderzee in the province of Friesland. By the lengthening of the Ketel jetties, and the quicker discharge of water down the improved bed of the Yssel, the mean summer level of the water at Kampen has risen since 1812, at high tide, from + 0·29 mètre A.P. to + 0·43 mètre A.P., and at low tide from + 0·21 mètre A.P. to + 0·24 mètre A.P.

The Estuaries.

Between the main land of the province of South Holland on the north, and the coast of Flanders on the south, the Leck, the Waal, the Meuse, and the Scheldt reach the sea through a maze of channels and creeks forming a large number of islands and shoals. The direction of the currents in these channels depends on the flow and ebb of the tide, and in a smaller degree on the volume of water discharged by the rivers, and is therefore very irregular. The sea coast, which trends south-west and north-east, has the same character as all that part of the North Sea shore, and is a continua-

tion of the chain of sand dunes that borders it, only broken by wide gaps where the estuaries run inland. In the Roman period these dunes extended much farther to the west, it is said, forming a band from 40 to 60 kilomètres in width; but they have been scoured away by the currents of the coast, and deposited farther inland, shoaling what was formerly deep water, and enlarging existing islands. These islands were embanked to some extent in the ninth century; and regulations respecting them prove that the dykes must have been of great importance in the thirteenth century, as is also shown by a law of Zeeland passed in the year 1256. The channels have been subject to great changes for the last three hundred years; creeks and lagoons have become dry which were formerly navigable, thus destroying the shipping of many towns which were flourishing in the eighteenth century.

The changes caused by the inundation of 1421 on the upper rivers also had their effect on the lower reaches, particularly on those of the Leck and New Meuse.

The tide flows from the south, and the ebb returns to the south; high water occurs sixteen minutes later at the Hook of Holland than near Brouwershaven, and at Kimpen two hours and five minutes later than at Willemstad on the Hollandsch Diep, and the ebb two hours and eighteen minutes later. This has had a disturbing influence on the currents in the Noord, the Killen, and the Old Meuse, and has injured the navigation of the New Meuse.

Where King William III. entered the Meuse, at Brielle, in 1691, with his whole fleet, there were in 1732 only two narrow channels, with 3 mètres depth of water; and in 1748 fishing boats could with difficulty cross the bar. Two ferry dams near Dordrecht had done much harm, and rapid deterioration had been aided by reclaiming large tracts of foreshore, so that the surface covered by the water in the New Meuse, which had been 4,387 hectares in 1732, was only 2,959 hectares in 1850. Ships drawing more than 3 mètres could not enter at Brielle even at high water, and had to come up by way of Hellevoetsluis and Dordrecht, and ships drawing more than 5 mètres had to make for Brouwershaven, and thence through the Volkerak to Dordrecht. Both passages, with their uncertain currents and intricate fairways, were inconvenient. To benefit the towns on the Meuse, a canal was made in 1829 through the island of Voorne from Hellevoetsluis to the Meuse, 10,544 mètres long and 5·10 mètres deep, and locks of a width of 14 mètres were constructed. Other plans had been proposed, as, for instance, to construct a canal through the island of Goerêe to the Brouwershavensche Gat. In the mean time improvements were effected in

all the above-mentioned branches and creeks. The Hollandsche Yssel was also canalised and deepened, and locks established above Gouda. The Noord and the Kielen were dredged, but were with difficulty kept at a depth of 4 mètres under low water.

In 1862 it was resolved to give a new mouth to the Meuse on the plans proposed by Mr. P. Caland, Inspector of the Waterstaat. The works were to consist of training the banks of the New Meuse from Krimpen to the width of 225 mètres, widening to 450 mètres at Vlaardingen, and of excavating the new mouth through the sand dunes to a width of 900 mètres between fascine jetties slightly bending southward, and ending in the sea at a depth of 7·50 mètres. Subsequent to 1858 some steps were taken in this direction between Rotterdam and the Scheur. In 1863 a small harbour of refuge was constructed on the sea coast near the proposed mouth, and the shore ends of the jetties were laid down. The next year the south dam was lengthened to 800 mètres. In 1865 an island near Delfshaven was united to the north bank, as had been another near Schiedam in 1856. The south jetty was lengthened to 1,000 mètres, that on the north to 500 mètres; and a gullet was excavated down to the bottom level along the centre line, 10 mètres wide at the bottom of the cutting. In 1866 a length of 200 mètres was added to the south, and of 300 mètres to the north jetty, and the gullet was excavated farther; the jetties in this and the following year were also strengthened by extra piling through the body of the fascine work and heavy stone pitching. In 1868 the north jetty was lengthened to 1,000 mètres, the canal further excavated and the tide admitted. In 1869 the old fairway through the Scheur was curtailed by groynes from both banks, and some dredging was done in the new channel; this deepened gradually by the scour to 1·90 mètre below low water in 1871, and the Scheur was closed by a dam about 0·40 mètre above low water. In the same year the north jetty was lengthened to 1,100 mètres. In 1872 the north jetty was lengthened to 1,460 mètres, the dam in the Scheur was raised to + 1·50 mètre A.P., or 0·60 mètre above high water, the depth in the new channel was increased to 3 mètres for a width of 500 mètres, and steamers drawing 3·20 mètres followed the new route. In 1873 the north jetty was lengthened to 1,800 mètres, and the dredging went on in the cutting. It was calculated that the new channel discharged 38,752,740 cubic mètres of water during ebb, and admitted 30,697,248 cubic mètres during the flow of the tide; the channel was also buoyed and lighted. In 1874 the north jetty was lengthened to 2,000 mètres, the south to 1,400 mètres; and in 1875

the latter was extended to 1,850 mètres; and again to 2,300 mètres in 1877. The channel reached a depth of 3·95 mètres below low water, and ships drawing 5·70 mètres passed through it without difficulty. Dredging and widening went on in the mean time, and ships drawing 5·70 mètres now come up to Rotterdam without breaking cargo, as, for instance, the transatlantic steamer "P. Caland," of 4,000 tons. At present a commission is considering the advisability of further improving this waterway.

The docks at Rotterdam have been of late years much enlarged, and many important and interesting works have been constructed at that city.

The estuaries are still being improved, and every year some good result is obtained. The navigable channels admit ships of 6 mètres draught up to Rotterdam; thence past Dordrecht to Gorinchem, through the Kil and the New Merwede, of 4 mètres. The fairway from Dordrecht to Brouwershaven is 5 to 6 mètres deep, the Old Meuse 4 mètres, and the Old Merwede 3 mètres. These are also the minimum depths along the Waal and Upper Rhine to Emmerick. In the Lower Rhine, Leck, and Yssel not more than 2 mètres depth of water can be calculated upon, except during floods.

The greatest danger to the island polders in the estuaries are rapid changes in the channels, and the currents scouring deep holes. When the bank is weakened in this way by a great depth of water approaching the dyke, it needs constant watching and heavy works, "sinkstukken" and stone pitching, to keep it from being undermined and washed out, taking the dyke with it, and thus opening the polder to the high tide. These so-called falls are frequent, and a source of considerable apprehension. The dykes are always carefully observed, and the submerged foreshores repeatedly sounded. The sea dykes on the islands are raised mostly to a height of + 4 mètres A.P., and in exposed situations are covered by heavy stone pitching in courses. The next great work to be taken in hand at the new mouth of the Meuse will be the better outfall of the Brabant Meuse.

The absence of calamities enjoyed by the country of late years is due in some measure to mild winters; but the improvements of the defence works warrant the hope that great devastations will in future be avoided, although the inhabitants of this low-lying and boggy land will never be quite safe from dangerous inroads from the North Sea and the Rhine.

The Paper is accompanied by fifteen maps and sections, from which Plates 10, 11, and 12 have been prepared.

APPENDIX I.

NEW MERWEDE.

EXPENDITURE, 1851–1875.

Years.	Land and Compensation.	Repairs and Maintenance.	New Works.	Total.
	Florins.	Florins.	Florins.	Florins.
1855	..	49,364	69,955	119,319
1856	16,553	83,726	40,983	141,262
1857	..	56,824	63,800	120,624
1858	30,000	..	92,819	122,819
1859	12,759	8,789	162,663	184,211
1860	26,000	7,450	107,492	140,942
1861	17,993	30,849	147,787	196,629
1862	40,325	91,958	251,033	383,316
1863	8,857	45,478	181,455	235,790
1864	40,770	33,331	291,321	365,422
1865	22,664	69,811	289,034	381,509
1866	1,696	27,068	266,441	295,205
1867	67,264	141,573	208,837	417,674
1868	117,767	158,788	170,457	447,012
1869	64,988	123,562	425,976	614,526
1870	114,611	145,936	299,600	560,147
1871	30,556	198,771	344,053	573,380
1872	19,156	124,769	199,551	343,476
1873	..	122,189	518,449	640,638
1874	2,525	140,016	565,695	708,236
1875	4,850	144,071	323,450	472,371
	639,334	1,804,323	5,020,851	7,464,508

APPENDIX II.

NEW MERWEDE.

Quantities Dredged by Steam Dredgers, and Cost of Dredging.

Years.	Quantities.	Cost.	Other Expenses.	Total.	Remarks.
	Cubic mètres.	Florins.	Florins.	Florins.	
1861	..	..	73,500[1]	73,500	[1] 25-HP. steam dredger and 3 scows iron.
1862	71,189	28,176	13,585[2]	41,761	[2] 11,780 for 20-HP. tug.
1863	95,505	28,945	16,795[3]	45,740	[3] 12-HP. steam dredger.
1864	303,643	105,387	36,585[4]	141,972	[4] 2 × 12-HP. steam dredger.
1865	340,000	112,815	59,565[5]	172,380	[5] 2 × 12-HP. steam dredger. and 6 scows.
1866	585,315	181,227	12,944[6]	194,171	[6] 20-HP. tug.
1867	400,000	116,000	..	116,000	
1868	250,848	96,000	4,400[7]	100,400	[7] Improvements to dredgers.
1869	413,135	128,294	6,600[8]	134,894	[8] Ditto.
1870	450,000	116,562	3,370[9]	119,932	[9] Repairs to dredgers.
1871	508,712	131,680	1,620[10]	133,300	[10] Ditto.
1872	541,407	126,399	8,537[11]	134,936	[11] Ditto.
1873	550,000	148,250	7,387[12]	155,637	[12] Ditto.
1874	600,000	189,966	..	189,966	
1875	656,769	179,885	..	179,885	
	5,806,523	1,689,586	244,888	1,934,474	Or 0·333 florin per cubic mètre; or, 4·62d. per cubic yard.

APPENDIX III.

Comparative Volumes of Water passing down the Branches of the Rhine, the Volume of the Undivided Upper Rhine Stream being taken equal to 9 Units, at Three different River Levels.

	At Mean River Level.			At 1 Mètre + Mean River.			At 1 Mètre − Mean River.		
	Waal.	N. Rhine.	Yssel.	Waal.	N. Rhine.	Yssel.	Waal.	N. Rhine.	Yssel.
Theoretical Volume.	6	2	1	6	2	1	6	2	1
Years.									
1841	6·50	1·73	0·77	6·40	1·80	0·80	..	..	..
1846	6·26	1·82	0·92	6·23	1·91	0·86	6·88	1·64	0·48
1851	6·11	2·01	0·88	6·03	2·04	0·93	6·44	1·92	0·64
1856	6·22	1·88	0·90	6·07	1·99	0·94	6·81	1·55	0·64
1861	6·36	1·80	0·84	..	..	..	6·63	1·70	0·67
1866	6·29	1·82	0·89	6·26	1·83	0·91	6·63	1·71	0·66
1871	6·30	1·74	0·96	6·20	1·84	0·96	6·50	1·74	0·76
						In 1871, 2 mètres + mean river.			
							6·09	1·85	1·06

(*Paper No. 1609.*)

"Account of Two Drainages in Ireland."

By John Hill, M. Inst. C.E.

The Rathdowney drainage district is a small tract of low-lying land near the town of Rathdowney, in the west part of the Queen's County. It is situated on the river Erkina, a tributary of the Nore, at the confluence of three other streams falling into the Erkina within a distance of 1 mile. There were 413 acres of land injuriously affected—about 100 acres being constantly submerged in the winter season, 150 acres frequently flooded, and the remaining 163 acres occasionally flooded. The principal portion of the tract is a deep alluvium, but about one-third is shallow moorland on gravel subsoil.

On examination it was found that the channel of the Erkina through the flooded lands was insufficient for the proper discharge of the water in rainy weather. It was tortuous, wholly inadequate in size, and was obstructed by a shoal at the lower end of the district, on which Coneyburrow bridge had been built on the line of road between Rathdowney and Abbeyleix. The catchment basin or area drained by the river and streams was 56·7 square miles, all comparatively low-lying land on the lower limestone formation, with some slight rising ground. It was distant about 12 miles from, and on the east side of, the Devil's Bit range of mountains, sheltered by them from the western winds, and uninfluenced by drainage from the mountains. The falls in the drains and streams into the flooded lands were gentle. On consideration of all the circumstances, it was decided to provide channels adequate to discharge 600 cubic feet of water per minute for each square mile of catchment basin (less than 1 cubic foot per acre), bringing up the total at the outfall to 34,020 cubic feet per minute.

The falls in the channels were determined by the longitudinal section of the river, and the depths from considerations regarding the drainage of the lands adjoining. The slope of the sides adopted is 1 to 1. The bottom breadths and the sizes of the channels were deduced in accordance with the rule given in Beardmore's "Manual of Hydrology," p. 8—

D, Discharge in cubic feet per minute.
V, Velocity in feet per minute.
h, Height of surface of water from bottom in feet.
b, Breadth of bottom „
a, Area of cross section $= (h + b) \times h$ „
c, Line of contact of water with bottom and sides.
m, Hydraulic mean depth $= \frac{a}{c}$.
f, Fall per mile in feet.
55, Coefficient for discharge in cubic feet per minute.

$$V = 55 \,.\, \sqrt{m \,.\, 2f}, \text{ or } V = 55\sqrt{\frac{a}{c} \,.\, 2f};$$

$$D = V \,.\, a, \text{ or } D = a \,.\, 55\sqrt{m \,.\, 2f}, \text{ or } D = a \,.\, 55\sqrt{\frac{a}{c} \,.\, 2f}.$$

The latter equations for V and D cleared of the radicles become—

$$V^2 = 55^2\,\frac{a}{c} \,.\, 2f, \text{ and}$$

$$D^2 = \frac{a^2 \,.\, 55^2 \,.\, a \,.\, 2f}{c}, \text{ or } D^2 = \frac{a^3 \,.\, 55^2 \,.\, 2f}{c}.$$

In this latter form it is very convenient for computation by logarithms; for instance, for the channel at the outlet with a fall of $2\frac{1}{2}$ feet per mile, depth of bottom 6 feet below the surface of land, height of water 5 feet, bottom breadth 23 feet:—

$$a = (5 + 23) \times 5 = 140$$
$$c = (2 \times \sqrt{2 \times 5^2}) + 23 = 37\cdot14$$

a —	140·00	log.	2·1461280
$2f$.	5·00	„	0·6989700
55^2 =	3025·00	„	3·4807254
C	37·14	„	8·4301581[1]
V^2			2)4·7559815
V =	238·8		2·3779908

a .	140·00	log.	2·1461280
a^3			6·4383840
$2f$.	5·00	„	0·6989700
55^2—	3025·00	„	3·4807254
C	37·14	„	8·4301581[1]
D^2			2)9·0482375
D =	33·428		4·5241188

The discharge is sufficiently near the estimated supply for practical purposes; an increase of 1 inch in depth would be about equal to it, and of 3 inches would exceed it by more than 2,000 cubic feet per minute, while the surface of the water would be 9 inches below the level of the land adjoining.

[1] The arithmetical complement of the logarithm.

The district was constituted under the Act 26 & 27 Vict. c. 88, "The Drainage and Improvement of Lands Act (Ireland), 1863."

The petition pursuant to the Act was presented to the Commissioners of Public Works in 1864; the inquiry was made by their inspector, Mr. Samuel U. Roberts, M. Inst. C.E., now one of the Commissioners of Public Works, who somewhat modified the design; and the Provisional Order was made, and confirmed by an Act in the ensuing session of Parliament.

Plans were prepared to widen, deepen, and straighten the Erkina river from Donaghmore bridge to a point in the townland of Coolnaboul, about 239 perches below Coneyburrow bridge, and for improving the Kilbreedy, Graignavallagh, and Rathdowney streams, as well as underpinning Coneyburrow bridge, and building an accommodation bridge in the townland of Donaghmore. Some delays took place, so that arrangements were only made for the execution of the works late in the year 1865, and they were completed in a satisfactory manner, in 1867, by Mr. Thomas Plunkett, the contractor.

There was little difficulty in the execution of the works, which consisted principally of clay excavation, with some rock at the lower end. The waterway of Coneyburrow bridge was deepened more than 6 feet, and the masonry underpinned nearly 8 feet; this was a risky operation, as the bridge was old, and the masonry defective.

The whole cost incurred was—

	£	£	s.	d.
For works	2,034			
„ superintendence	115			
		2,149	0	0
„ legal and other expenses, and interest on money borrowed .		499	6	3
		2,648	6	3

The money was borrowed from the Commissioners of Public Works, and will be repaid in twenty-two years from 1868, by a rent-charge of £172 2*s.* 10*d.* per annum, payable half-yearly. The estimated increase in the yearly value of the land by the works is £189.

The works have been moderately well maintained by the Drainage Board appointed under the Act. Occasionally the water fills the channel, and overflows a small extent of land along the river sides; but the water soon subsides, the longest time it remains in flood being about two days.

The value of the improvement to the lands is greater than was

anticipated, but the water in flood time is somewhat more than was estimated, and the size of the channel inadequate. Probably if the channels were perfectly maintained they might discharge the flood waters, but very little impediment is sufficient to cause the water to overflow; and although it has only occurred to the small extent mentioned, the drainage must be considered imperfect.

The Sixmile Bridge drainage district is in the south-east part of county Clare. It consists of low-lying land along the river Ownogarney and its tributaries. The river rises from Lough Bridget, and, flowing southwards for about 16 miles, falls into the Shannon at Bunratty. There are five lakes along its course—Kilgorey Lough, Doon Lough, Lough Gar, Ballymulcashel Lough, and Castle Lake. There is a range of hills on the east side for the whole length, rising at one point, Cragnamurragh, to 1,729 feet above the sea; and three large tributaries flow through the valleys and fall into Doon Lough—the Ballymacdonnell, Killurin, and Glenomra rivers; one stream falls into Kilgorey Lough; and several small streams flow down the face of the hills (which are in many places very steep) into the river. On the west side the country is comparatively flat with some rising ground, not more than 200 feet at any place above sea level. One tributary on this side, the Mountallon stream, rises from Clonbrick Lough, flows through a series of lakes, and falls into Lough Gar near Doon Lough.

On examination, it was found that 2,595 acres of land were injured, of which about 1,000 acres consisted of deep rich alluvium, about 500 acres were thin moorland, and the remainder of intermediate quality—all liable to occasional flooding, while the most valuable portion was subject to frequent inundations. The river channels were tortuous, defective in size, and obstructed by fords, fishing-weirs, bridges with inadequate waterways, and such impediments to the proper discharge of the water that even in dry summer weather a considerable portion of the land was in swamps, and the channels only approachable by wading.

The Ownogarney river and the country on the west side are on the lower limestone formation; while the country on the east side is on clay slate and the old red sandstone, the course of the river being nearly along the junction of the limestone and sandstone.

The catchment basin drained by the main river and its tributaries has an area of 61·6 square miles; the portion about the upper end and on the west side of the main river course is comparatively flat, but on the east side it is hilly.

The improvements extend from Lough Bridget to the old Oil Mill bridge at the then head of the tidal influence, about 3½ miles from the junction with the Shannon; but in consequence of the improvements the tidal water now comes up nearly to Sixmile Bridge. The fall in the river is 91 feet, and is very irregular. The bottom of the channel has been made, as nearly as practicable, from 5 feet in the upper, to 7 feet in the lower portions, below the level of the adjoining ground; the side slopes are 1 to 1 in clay, and ¼ to 1 in rock; and the bottom breadths, and consequent size of the channels, were computed (in a similar manner as described for the Rathdowney drainage) to provide for the discharge of flood waters—Doon Lough, Ballymulcashel Lough and Castle Lake, being made available as reservoirs for regulating the flow of water in the main channel.

TABLE of CATCHMENT BASINS and CONDUITS.

Area Drained.	Description of Catchment Basin, and Estimated Quantity supplied in Floods.	Discharge per Minute.	Fall per Mile.	Conduit. Bottom Breadth.	Conduit. Height of Water.
Square miles.	Per Square Mile.	Cubic feet.	Feet.	Feet.	Feet.
11·8	Lough Bridget to Doon Lough, low flat land, 807 cubic feet per minute . .	9,523	2·1	10	3·50
15·1	Ballymacdonnell and Killurin rivers, very steep fall from high mountains, 1,600 cubic feet per minute . . .	24,160	7·7	16	3·50
13·9	Glenomra river, 12 square miles, very steep, 1,600 cubic feet per minute, 1·9 square mile, moderate, 840 cubic feet per minute	20,800	6·0	15	3·50
5.4	Mountallon stream, Clonbrick Lough to Lough Gar, low flat lands, 807 cubic feet per minute	4,358	2·4	8	2·50
46·2	Total supply into Doon Lough .	58,841			
	Discharge from Doon Lough . . .	36,960	6·9	24	3·75
8·3	Doon Lough to Pollagh bridge, very steep, 1,600 cubic feet per minute .	13,280	..	..	..
		50,240	5·8	26	4·50
3·5	About Ballymulcashel Lough and Castle Lake, steep, 1,200 cubic feet per minute	4,200	..	..	..
58·0	Total supply into Ballymulcashel Lough and Castle Lake . .	54,440			
	Discharge from Castle Lake . . .	46,400	4·1	26	5·00
3·6	Castle Lake to Oil Mill bridge, moderately steep, 900 cubic feet per minute	3,240	4·1	28	5·00
61·6		49,640	2·5	30	5·60

The channels in rock cutting with slopes of $\frac{1}{4}$ to 1, and the waterway of bridges with vertical sides, were made equivalent to those above stated.

Doon Lough covers 392 acres 31 perches = 17,084,232 superficial feet. The estimated quantity of water supplied to it in flood time is 58,841 cubic feet per minute, or 84,731,040 cubic feet in twenty-four hours, and $\frac{84,731,040}{17,084,232} = 4 \cdot 96$, which indicates that this quantity of water would raise the lake about 5 feet in twenty-four hours; but it did not do this at any time, as the water spread over a large area on the low ground adjoining: the range between the maximum height and minimum height was 5·2 feet. The difference between the supply and the proposed discharge is 58,841 – 36,960 = 21,881 cubic feet per minute, or 31,508,640 in twenty-four hours, and $\frac{31,508,640}{17,084,232} = 1 \cdot 84$; so that a rise in the lake to that extent might take place in twenty-four hours, and consequently an extraordinary flood lasting three days might raise it $3 \times 1 \cdot 84 = 5 \cdot 52$ feet. The lake was to be lowered by the drainage works about 6 feet below its ordinary summer level, and it was anticipated that it would not rise to the previous summer level in the highest floods.

Ballymulcashel Lough has an area of 30 acres 2 roods, and Castle Lake 91 acres 2 roods 16 perches, together 122 acres 16 perches = 5,318,676 superficial feet. The difference between the estimated supply and the proposed discharge is 54,440 – 46,400 = 8,040 cubic feet per minute, or 11,577,600 in twenty-four hours, and $\frac{11,577,600}{5,318,676}$ $= 2 \cdot 18$, indicating that a rise in the lake to that extent might take place in twenty-four hours, and in extraordinary floods lasting three days might rise $3 \times 2 \cdot 18 = 6 \cdot 54$ feet. It never did so previously, as the water had a large space to spread over. Castle Lake was proposed to be lowered 6 feet, and it was calculated that it would not, at the highest floods, rise to its former summer level.

The district was constituted under the provisions of the Act 26 & 27 Vict. c. 88, in the year 1864. The inquiry directed by the Act was conducted by Mr. Roberts, who acted in the Rathdowney district; he revised the design, and effected several valuable improvements. A provisional order was made by the Commissioners of Public Works, which was confirmed by an Act in the ensuing session of Parliament. Detailed surveys, plans, sections, and specifications of works, were made, to deepen, widen, and improve the river channels, remove eel-weirs, remove and alter mill sites,

construct regulating weirs and embankments along the channels of the rivers, build weir walls for sandtraps, sink and improve streams and drains, reconstruct and improve twenty-one public road bridges, and to execute sundry other works incidental to, and necessarily connected with, the drainage. There were 23 miles of main channel to be operated upon—5 miles of lakes intervening—6·1 miles of streams and drains to be deepened, sunk, and adjusted, and 10·7 miles of back drains to be opened and constructed; in all, 39·8 miles of waterway to be made or improved.

Operations were commenced in August 1865 on the main river, from the old Oil Mill bridge to Doon Lough, as it formed the outlet for the remaining part of the district; but the contractor who undertook the works unfortunately failed, and in July 1866 they were taken up by the Drainage Board, and ultimately completed in September 1868. They were sufficiently advanced to enable the other portions of the district to be proceeded with early in 1867, and these were finished early in 1872.

On the Ownogarney river, between the Oil Mill bridge and Doon Lough, the operations were retarded by sudden floods carrying away dams, &c.; but for the remainder of the district to Lough Bridget, and on the Mountallon stream, the operations were simple excavations in clay, gravel, and a considerable portion in rock.

On the Ballymacdonnell river, when the excavations were nearly completed, on the 20th of August 1867, a heavy fall of rain occurred near the source, and a torrent ensued, which tore away the sides of the channel to a considerable extent. On the 22nd of October following another fall of rain produced a torrent, which further damaged, and in some portions utterly obliterated and destroyed, the channel and works previously constructed. The damaged portion, about 3 miles in length of river channel, was then put in charge of the Author for repair. Early in April the channel was formed; the sides were trimmed and permanently secured for about 1¼ mile in length, with dwarf stone walls at each side, from 3½ to 5 feet high, and the remainder was sodded and stoned in places, and completed in October, at a cost of £974. The summer of 1868 was dry, and particularly favourable for the execution of the work, which was effected economically. Had the season been adverse it would have been a difficult operation, as the stones for the dwarf walls had to be raised in various places, and carted across soft ground to the river course.

The Glenomra river, from about ½ mile from its mouth in Doon Lough to its source, is in clay slate formation. At the upper end it

is fed by several small streams flowing down the steep slopes of the hills, the surface being soft shale of the clay slate, very friable, and liable to come down in great quantities. These streams were previously embanked near the junctions with the main river over the flat ground, and the banks raised from time to time, as the channels were filled with *débris*. On one of them the bed of the channel was 12 feet, and the top of the embankments 15 feet high, above the ground on each side. It was determined to take additional precautions against this tendency of the *débris* to run down, by securing the "scaurs," or precipitous banks of the streams, by stonework, and where stones could not be procured, to use wickerwork, and to construct cesspools or sandtraps by building weir walls across their courses at convenient places, to check the flow of water and to collect the *débris*. A length of 244 perches = $\frac{3}{8}$ mile, was thus secured in the summer of 1867, and up to the completion of the works, in 1872, there was no appearance of *débris* at the sandtraps, which were apparently useless.

The side slopes adopted for the channels in the district, 1 to 1, give less facilities for cattle to get into the channels than flatter slopes, which would be advisable as regards the stability of the banks. In the Glenomra river, flatter slopes would have been better for the sides, as the channels had to be made of considerable capacity to discharge floods; while the dry weather volume of water is small, and might be concentrated in a narrower breadth at the bottom, to give the stream greater scouring power, and to keep the channel clear.

There was one mistake in the design of the works. From Doon Lough there is a narrow deep prolongation of the lake by Lough Gar to a point near Ahaclare bridge, where the river channel commences, and which was unfortunately made horizontal for 1,200 feet, and only of the same dimensions as the extended channel, which has a fall of 6·9 feet per mile. The defect was not noticed until a short time before the close of the works. It was attempted to correct it by making the end next the prolongation of the lake bell-mouthed, and widening the channel to Ahaclare bridge, but it is a serious drawback to the efficiency of the drainage.

The works were completed in the autumn of 1870, at a cost of £14,526 2*s.* 4*d.*; the purchase of land, mill, mill site, damages, legal expenses, superintendence, and interest on borrowed money, which amounted to £5,378 9*s.* 11*d.*, raised the total cost to £19,904 12*s.* 3*d.*

The area of land drained or improved is 2,595 acres 4 perches. The original annual value of the land was estimated at £1,309 18*s.* 3*d.*; and the increase on this, by reason of the improvement by the drainage, at £1,229 14*s.* 11*d.* The annual rent-charge to pay off the amount of the award, which was borrowed from the Commissioners of Public Works, is £1,300 9*s.* 2*d.*, which will clear off the debt in twenty-two years.

The works have been moderately well maintained by the Drainage Board appointed according to the provisions of the Act, and the channels are kept in fair order. Some time after the completion of the works it was perceived that the sandtraps were not filled, and were apparently useless, and the Board withdrew a caretaker appointed to preserve the wickerwork along the "scaurs." In a short time the wickerwork was all taken away by the peasantry for fuel, and the first flood that ensued tore down the *débris* from the face of the "scaurs," and filled the sandtraps. An annual expenditure of about £40 has thus been incurred to clear the sandtraps, whereas about £10 per annum would have maintained the wickerwork. But it was fortunate that both precautions were adopted, as had the *débris* gone down into the channels, it would have been an expensive operation to clear them out properly, and intolerable to have had to do so periodically.

In the upper reaches of the Glenomra and Ballymacdonnell and Killurin rivers, in addition to the provision of channels of the sizes computed, as before mentioned, the stuff excavated was trimmed into embankments on each side of the channel, forming a large conduit, and the discharge of the surface water from the adjoining lands is provided for by back drains. The embankments have prevented damage from two or three extraordinary falls of rain about the source of those rivers. The channels adopted in the remainder of the district are only of sufficient capacity to discharge the flood waters; and, since their completion in 1871, the water has not overflowed the banks, except about 3 acres near Ahaclare bridge, where the error in the projection of the channel was made. The lakes have answered the purpose of reservoirs, and have regulated the floods, as anticipated; nor have they at any time been filled to the former summer level. The estimated increase in the value of land has been more than realised, and the general improvement of the district is most satisfactory.

This communication is accompanied by several maps and sections, from which Plate 13 has been compiled.

(*Paper No. 1631.*)

"Brief Account of the Woosung Railway."

By Richard Christopher Rapier, M. Inst. C.E.

For many years engineers have been anxious to see a beginning of railways in China. Any success in this direction would not only open an important field of engineering labour, but would also greatly promote economical intercourse with that country. Many attempts have been made; but difficulty has always arisen from the unwillingness of the local authorities to sanction the proposed works, and from the reluctance of the Central Government to interfere with the responsibilities of its Viceroys. After much patient waiting, Messrs. Jardine, Matheson & Co., of Shanghai, and their friends succeeded in acquiring a strip of land for a distance of about 9 miles, from Shanghai to Woosung. As they possessed no compulsory powers, this was, of course, a costly proceeding, and the funds at the disposal of the committee were nearly exhausted in the purchase of the necessary land and graves. Still it was felt that the effort should not be abandoned without trial, and a small company was formed under the title of the Woosung Road Company, with the intention of constructing a road, tramroad, or railroad, as opportunity might offer. In the course of the year 1875 the Author submitted to Messrs. Jardine, Matheson & Co. an estimate for a railway on a small scale, which could be carried out at comparatively little further outlay, in addition to that which had already been incurred. It was also thought that, as it was doubtful how far the opposition to railways might extend, and what character it might assume, it would be advantageous for the first railway to be of moderate proportions. With this view, a very small engine was proposed to be sent in the first instance. In anticipation of some opening occurring in China, an engine had been specially built by Messrs. Ransomes and Rapier, of Ipswich. It weighed about 30 cwt. in working order, and it easily maintained a speed of 15 or 20 miles an hour. It was intended that if this little engine were not objected to, it should be immediately followed by others of 8 or 10 tons weight.

A contract was now entered into between the Woosung Road Company and Mr. John Dixon, Assoc. M. Inst. C.E., to complete

and equip a railway on the basis of the estimate above referred to, Mr. Dixon agreeing to take a large part of his payment in shares in the undertaking. The materials were sent out in October 1875, and arrived at the beginning of the following year.

An embankment, about 8 feet high, had been constructed along nearly the whole length of the line, in order to place the railway above flood level. This embankment had been made, from time to time, as the land was purchased, so as to prevent the previous owners resuming cultivation and possession.

The laying of the permanent way was commenced in January, 1876. The rails were of the Vignoles section, weighing 26 lbs. per yard, and were laid on cross sleepers, the gauge of the line being 2 feet 6 inches. The gauge was purposely fixed thus narrow, partly for economy, and partly to ensure the thorough consideration of the gauge question at the next stage of railway making. For a populous country like China, everyone concerned was in favour of the gauge of 4 feet 8½ inches, but funds did not admit of its adoption for the experimental attempt.

There were about twenty small wooden bridges on the line over narrow creeks, but no works of importance. The chief item of expense was the ballast. This had to be brought a distance of about 70 miles in boats, at a cost of about *5s.* per cubic yard.

The little engine began to run on the 14th of February, 1876, and was received by the Chinese with enthusiasm. There were frequently as many as ten thousand visitors in a single day to see it at work. It is noteworthy that the news of this favourable reception reached London the same evening.

There seemed now to be no likelihood of opposition on the part of the people, and the completion of the line with its permanent engines and rolling stock was pushed forward as rapidly as possible. The first 4 miles were opened for public traffic on the 3rd of July, 1876, and the whole line was completed in August, but was not opened until the 1st of December, of that year. Of the permanent engines, two weighed 9 tons, and one 13 tons, in working order. The rolling stock consisted of two first-class, two second-class, and eight third-class carriages, each accommodating about twenty-five passengers. It frequently happened, however, that the carriages had double their proper complement of passengers without any accident occurring. Indeed, during the whole working of the railway there was no accident to life or limb, except in the case of one man who committed suicide; and no accident to property, excepting that a spark from an engine once caused damage to the extent of £90.

The daily service of trains consisted of seven each way, performing the distance of 9 miles in thirty-five minutes, with two intermediate stoppages. The first-class fare was one dollar, the second-class half a dollar, and the third-class one-sixth of a dollar for a single ticket. Nearly all the passengers travelled third-class, there being only one first-class passenger and two second-class passengers to eighty third-class. The number of passengers per train averaged about one hundred, and frequently exceeded three hundred. The station-masters, drivers and guards were Englishmen. The booking-clerks, firemen and platelayers were Chinese. They were very tractable, and discharged their duties with efficiency and success.

A principal objection offered to railways in China has always been an alleged fear of depreciation of property near the line, owing to the disturbance of the "spirits of the air and of the earth." The only effect this railway had on property was the usual one, to cause a great increase in the market value of land and houses near it. The village of Kung-wan, the principal intermediate station, experienced advantages perceptible at every turn. Besides the more substantial evidences of prosperity, there was at the stations a constant stand of wheelbarrows, just like an English cab-rank. Boatmen also obtained grattly increased occupation. It was satisfactory that so practical an answer was at once given to the principal objections which have been urged against railways in China.

The railway was in itself highly successful, being freely used by all classes of the community. There can be little doubt that the experiment would have been continued, had it not been for the untoward dispute between the British and Chinese Governments with reference to the unfortunate murder of Mr. Margary This dispute gave the Chinese authorities an opportunity of alleging a grievance in the matter of the railway. The difficulty was eventually settled by the suggestion of Li Hung Chang, that the Chinese Government should purchase the undertaking. As that statesman was known to hold very enlightened views, this proposition was acceded to by the company. It was, however, exceedingly distasteful to the Governor of the province, who had to carry out and complete the arrangements. The purchase sum for the railway was fixed at 285,000 taels, or about £78,000 sterling, so as just to cover the outlay made by the company, and the final instalment was paid in the month of October 1877.

In the meantime, Ting Futai, the Governor of Formosa, had expressed a desire to begin railway work in that island. The

Governor of Nankin therefore availed himself of this opportunity to get rid of the railway of which he was now the possessor, but which he did not wish to keep. Every effort was made to avert so retrograde a step. His Excellency Kuo Sung Tao, the Chinese Minister in London, made representations on the subject, which were also endorsed by the British Government; but all was to no purpose. The railway was at the mercy of the Governor of Nankin, who was annoyed at having been obliged to arrange for its purchase, on behalf of his Government, against his will. He ordered that the whole of the materials and plant should be sent by ship to the Island of Formosa. The shipment was carried out, but Ting Futai did not know that skilled engineers are a necessary part of any railway enterprise, and so no arrangements were made for any of the staff of the line to accompany the plant. Consequently the materials and machinery were landed in such a careless and negligent manner, that it is scarcely anticipated they can prove of any service.

There were about eighty shareholders in the undertaking, of whom about forty were Chinese, but the funds were chiefly found by the English subscribers. Mr. G. J. Morrison, M. Inst. C.E., was the resident engineer, and Mr. G. B. Bruce, M. Inst. C.E., was the honorary engineer in England.

Mr. Morrison has presented to the Library of the Institution a manuscript volume containing an authentic account of the undertaking, together with a full copy of all the correspondence which at any time passed with the Chinese authorities on the subject. This latter is of especial interest in view of the allegations which have been made to the disadvantage of the promoters of the undertaking; and it is of scarcely less interest in the glimpse which it gives of the Chinese view of such matters. This statement of all the facts affords complete evidence as to the entire *bona fides* of the company throughout. Mr. Morrison continues to reside at Shanghai, with the hope of making a substantial beginning of railways in a little time.

(*Paper No. 1659.*)

"On Cushing's Reversible Level."

By EDWARD HENRY COURTNEY, Major R.E.

EVERY practical engineer is aware of the inconvenience attending Gravatt's adjustment for collimation in all levelling instruments, where the telescope is a fixture in its supports. It has occurred to Mr. Cushing, Inspector of Scientific Instruments, India Office, to get rid of this inconvenience, by making the eye-end and the object-end of the telescope interchangeable. For this purpose he fixes to the internal tube of the telescope a gun-metal socket, which is turned and ground with a short conical fitting and wide flange, to receive the eye-end with its eye piece and diaphragm. On the opposite end of the outer tube a precisely similar fitting receives the cell containing the object-glass, both of the ends being identical as regards the fitting, though the object-end is necessarily rather longer than the other, on account of its having to carry, on the outside, the cover or dew cap. The eye-end is attached to the telescope by two screws placed 180° apart in the flange of its socket, which screws are not intended to be taken out. Corresponding holes in the flange of the eye-end allow it to be inserted in its socket, when a short rotary motion from left to right will bring it into its proper position against a stop. The object-glass cell has precisely the same kind of attachment, and will, like the eye-end, fit the socket at either end of the telescope.

Another valuable improvement in this level is the abolition of the spider lines, which have till now been the weakest part of the instrument, and a never-failing source of anxiety to engineers, especially when serving in out-of-the-way places where there are no means of getting them replaced. In lieu of these, Mr. Cushing substitutes fine and well-defined lines, ruled with much skill and care by a diamond on a disc of plane and parallel glass.[1] This

[1] The idea of having "lines on glass" is by no means a new one, as General Sabine, R.A.,—formerly President of the Royal Society—in his pendulum observations about the year 1822, had a transit instrument fitted in this way. In addition to this, several of the instruments used twenty years ago on the Ordnance Survey were similarly fitted, but as these glass lines were liable to a little roughness on their edge, they were given up by the Survey Officers, as not being such even lines as the spider threads; besides, they were not capable of being cleaned when dust lodged on the glass.

disc fits into a sliding diaphragm, inserted in the interior of the eye-end of the telescope, and provided with two screws for vertical collimation. A valuable part of the invention is, that even after the instrument has been adjusted the eye-end can be removed from its socket, and the cross lines cleaned (if necessary), and replaced again in position, without in any way disturbing the adjustment. The lines will bear a high magnifying power, and are, of course, as applicable to theodolites as to levels.

Great care has been bestowed on the construction of all other parts of this level. The instrument has been made by Messrs. T. Cooke and Son, of York, and is on the tribrach principle. The

FIG. 1.

FIG. 2. FIG. 3. FIG. 4. FIG. 5.

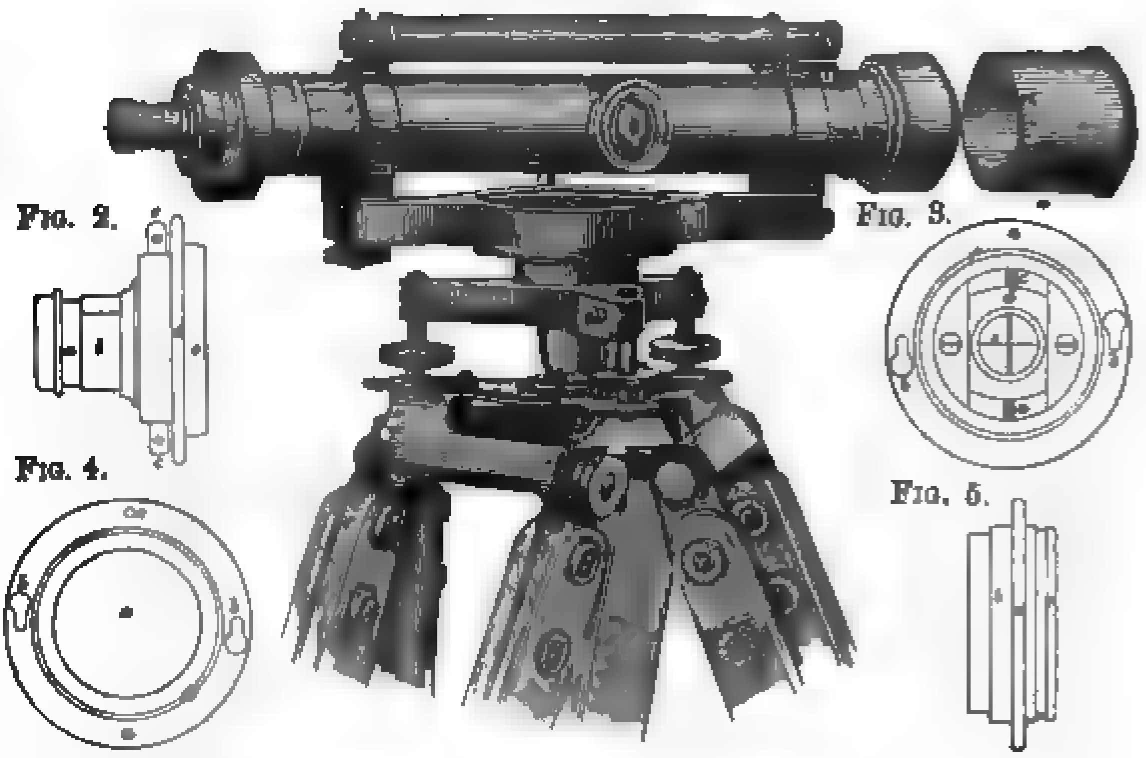


Fig. 2. Eye-end (removed from telescope): (a) eye-piece, (b) eye-piece socket, (c) collimation screws, (d) flange, (e) fitting for socket of telescope.
Fig. 3. Eye-end (plan of interior): (a) flange, (b) holes for attachment screws, (c) collimation screws, (d) sliding diaphragm, (e) disc with cross lines, (f) fitting for socket of telescope.
Fig. 4. Object-glass cell: (a) flange, (b) holes for attachment to telescope, (c) hole for small fixing screw, (d) milled edge for turning and removing cell, (e) object-glass.
Fig. 5. Object-glass cell: (a) flange, (b) fitting for telescope socket, (c) milled edge with hollow behind for firmer grip.

horizontal limb and the tribrach are both cast hollow underneath, so as to give a maximum amount of strength and rigidity with a minimum amount of metal. The ends of the horizontal limb carry the supports of the telescope; but a new feature is introduced in their attachment, for though the support nearest the object-end is in contact with the limb, it is capable of a slight rocking motion in the direction of the axis of the telescope, so as to admit of the second adjustment (hereafter described), whilst the other support

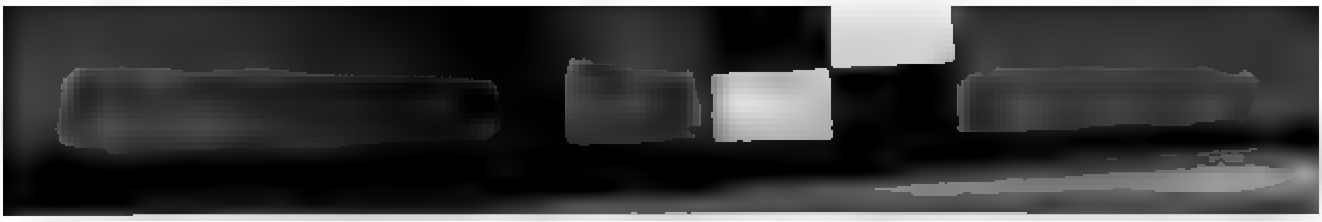
is provided with two large nuts for clamping and permanently securing the telescope to the opposite end of the limb when this adjustment has been performed. The object glass of the telescope has a focal length of 14 inches, and a clear aperture of 1·6 inch; while the bubble tube, which is about 7 inches long, and has an angular value of about 5″ of arc for each of its graduations, is carried immediately above the telescope, one end being attached to one of the telescope supports, and the other end secured by two opposing nuts, for purposes of adjustment, to the top of the other support. The usual small cross-level is also provided.

There are three adjustments for this instrument: 1st. The vertical collimation; 2nd. To make the line of collimation perpendicular to the vertical axis; 3rd. To set the bubble tube parallel to the line of collimation.

1st. *The vertical collimation.*—Set up the instrument on its stand, either in or out of doors, with one foot-screw under the telescope, and without reference to the level of the instrument. Take out the small fixing screw at the top of the object-glass cell, and, having focussed the cross lines, direct the telescope on any convenient object,[1] and bisect it with the horizontal line, ascertaining at the same time that there is no parallax in the telescope. Now carefully turn the eye-end in its socket from right to left, until the holes in the flange of the eye-end are opposite the heads of the screws in the socket, and remove it; then replace it again, but in an inverted position, taking care to turn the eye-end from left to right until it comes to a stop, when the lines will be in their proper position. If the point be still bisected, the collimation is perfect; but if not, correct half the distance of its deviation from the horizontal line by the foot-screw under the telescope, and the other half by the two screws that give vertical motion to the diaphragm carrying the disc with the cross lines. Repeat till perfect.

2nd. *To make the line of collimation perpendicular to the vertical axis.*—The object being now bisected, and all parallax eliminated, remove the eye-end and the object-glass cell from their respective sockets, and place them in the opposite ends of the telescope. If the object is still bisected on turning the telescope half round, the line of collimation is perpendicular to the vertical axis; but if not, correct half the error by the two large clamping nuts at one end of the horizontal limb, and the other half by the foot-screw under

[1] If this be done in-doors, a small circular dot on a sheet of note paper, placed about 20 feet from the instrument, will answer the purpose.



the telescope. As soon as it is found that the eye- and object-ends can be reversed without any apparent change of position in the object intersected, the small fixing screw should be returned, and the object cell made secure. It is important, in changing the object-glass from end to end, to keep that part of the cell which has the small screw-hole in it always uppermost.

3rd. *To set the bubble tube parallel to the line of collimation.*—Level the instrument stand approximately by the legs, and turn the telescope so that it is parallel to two foot-screws, bringing the bubble by their motion to the centre of its run. If it remain so on turning the telescope half round, the level is correct; but if not, bring the bubble halfway back by the foot-screws over which it stands, and the other half by the two opposing nuts at the eye-end of the bubble-tube. Having perfected this, the levelling must be completed by turning the telescope a quarter round, so that one end of the level is over the third foot-screw, by which the bubble must be brought to the centre of its run. The bubble should now remain in the centre during a complete revolution, and the small cross-level can then be adjusted.

It will be seen from the above that the facility of adjustment of the Y level is preserved, while at the same time the superior compactness, increased optical power, and greater stability of adjustment of the Dumpy level are retained. The substitution of fine lines ruled on glass for the spider lines hitherto in use is also a decided improvement. This instrument will therefore undoubtedly prove of the greatest practical utility to all surveyors. The Author is indebted to Mr. Cushing, not only for allowing him to inspect the instruments, but also for furnishing him with the necessary descriptions and drawings. Twenty of these levels have been ordered for the Indian Government.

(*Paper No. 1663.*)

"Experiments on the Resistance to Horizontal Stress of Timber Piling."

By John Watt Sandeman, M. Inst. C.E.

These experiments were undertaken to ascertain the amount of resistance opposed to the horizontal movement of timber piling by different strata, such as clay, sand, and forced material; also to determine the length necessary to be provided for, in back tie or anchor piles, with a view to economy in the construction of an extensive amount of river quayage. The results are recorded as affording a few practical data for elucidating these questions, in reference to which, so far as the Author is aware, no experiments have hitherto been made.

For each experiment two piles were driven (Figs. 1 and 2), at distances of 20 feet apart, and slightly inclined from the vertical; one representing the front, and the other the back tie pile in an ordinary timber quay. The front piles were securely strutted to resist horizontal stress, the lower ends of the struts abutting against short piles. The back piles were free to move towards the front piles under the influence of the stress. The horizontal movement was measured from a plumb-line at the levels indicated (Figs. 3 to 10), which show the inclination of the back piles in each case previous to the application of any stress. The measurements recorded in the lower columns of the table do not however represent the total distances through which the back piles moved. The actual distances at the same levels would probably be at least twice those given in the table, dependent on the depth below the ground at which any movement of the piles took place. In experiments Nos. 2 to 5 the back piles were pulled beyond a vertical line, as indicated by the horizontal measurements in the table being greater than those in Figs. 4 to 7.

The stress was applied at different levels between the piles by chain blocks and fall attached to each, the loose end of the chain being fastened to smaller blocks with a rope fall, the end of which was conveyed to a winch. The stress was registered by one of Duckham's 20-ton hydrostatic weighing machines.

The square piles were of Baltic red pine, the round piles of English forest larch.

The following data are afforded from the results of the experiments :—

First. The amount of resistance opposed to the horizontal (or partially radial) movement of timber piling by different natures of ground.

Second. The variation in the amount of resistance which different strata oppose to horizontal movement—loose ashes affording the least, clay more, and sand the greatest amount of resistance, as instanced by experiments, Nos. 2 to 6.

Third. The amount of increase in the resistance to horizontal stress obtained by planking upon tie piles, instanced by comparing experiments Nos. 4 and 5 with experiments Nos. 7 and 8.

Fourth. The length necessary to be provided for in back tie piles.

From the fact that three piles (experiments Nos. 3, 4, and 7), driven 15 feet into different strata, broke off at about 5 feet below the surface of the ground, it may be inferred that a tie pile at a depth of about 15 feet into the ground would meet with as much resistance to horizontal stress (applied at the level of the ground) as if the pile extended to any greater depth.

The communication is illustrated by a drawing, from which Plate 14 has been engraved.

[Table.

TABLE SHOWING the RESULTS of EXPERIMENTS on the RESISTANCE to

—	Stress applied above Ground Level.	Stress applied near		
	Experiment No. 1. Square Piles.	Experiment No. 2. Round Piles.	Experiment No. 3. Square Piles.	Experiment No. 4. Square Piles.
Nature of ground	Clay	Loose ashes and clinkers	Ashes and clinkers to depth of 12′, hard ground below	Clay
Length and diameter of piles	24′3″ × 12″ × 12½″	26′ × 12″ D. at ground level	20′ × 12½″ × 12″	24′ 3″ × 11½″ square
Inclination of pile	1 in 10¾	1 in 29	1 in 12	1 in 10¾
Depth of pile in ground	15′	18′	15′	15′
Height of pile above ground	9′ 3″	8′	5′	9′ 3″
Level at which stress was applied, + above, − below, original ground	+ 6′ 6″	About + 6″	About + 6″	About + 6″
Length and breadth of planks on back piles	..	..	..	..
Position of planks	..	..	..	..
Nature and depth of forced materials heaped against planking on back piles	..	..	..	..

The numbers in the columns below indicate the movement of the back piles

Stress in Tons.	1st Trial.	1st Trial.	1st Trial.	2nd Trial.	3rd Trial.	1st Trial.	2nd Trial.
1	1¼	1	..	..	..	..	..
2	2⅜		..	..	..	1/16	..
3	3	1½	1/16	..	..	3/16	..
4	Upon increasing the stress beyond 3 tons the pile yielded, and came out of the ground so easily as to prevent the continuance of the experiment.	1⅞	¼	..	..	⅜	..
5		..	⅜	..	..	1	4⅜
6		3½	1 3/32	2¼	5	1⅜	..
7		6	3¼	2½	..	1¾	..
8		11	..	3¼	5⅛	2⅜	4⅝
9		After 8 tons stress the pile came away so easily that no more stress could be applied.	..	4½	5¼	2⅞	4⅞
10			..	..	5¾	3¾	5
11			With 11 tons stress the pile broke off at 5′ 5″ below the ground level.			4⅜	5¼
11½						..	..
12						..	7⅛
12½						..	..
13						With 13 tons pile broke off at 5′ 2″ below the ground level.	
13½			..				
14			..				
15		..	..				
16		..	..				
17	..	..	..				
18	..	..	..			..	
19	..	..	..			..	
20	..	..	..			..	
(Probably) 23	..	..	..			..	

Weighing machine did not register above 20 tons, but index hand went beyond it.

Horizontal Stress afforded to Timber Piling by different Soils, &c.

Ground Level.		Stress applied below Ground Level.	
Experiment No. 5. Square Piles.	Experiment No. 6. Square Piles.	Experiment No. 7. Square Piles.	Experiment No. 8. Square Piles.
Clay	Sand	Clay	Clay.
16′ × 12¼″ square	24′ 6″ × 12¼″ square	25′ × 12″ square	15′ 6″ × 12″ × 11½″.
1 in 12	1 in 9	1 in 11½	1 in 12½.
10′	14′	(Original) 15′ (Forced) 5′ 6″	(Original) 10′. (Forced) 5′ 6″.
6′	10′ 6″	(Original) 10′ (Forced) 4′ 6″	(Original) 5′ 6″. (Forced) 0′ 0″.
About + 6″	About + 6″	About + 6″ and − 5′ forced	About − 2′ and − 7′ 6″ forced.
..	..	Two planks 10′ long and 9″ wide	10′ long and 5′ 6″ in total width.
..	..	+ 5′ 6″, covered by forced material for 8′ in length	Top + 5′ 6″, fully covered by forced material.
..	..	Sand and ashes 5′ 6″ deep, and extending 9′ in front of piles	Sand and ashes 5′ 6″ above and 3′ below ground level, and extending 10′ in front of piles.[1]

[1] A trench 3′ deep was excavated in the line of the piles, to enable the stress to be applied lower.

under the influence of the stress, measured in inches, as described in the Paper.

1st Trial.	2nd Trial.	3rd Trial.	4th Trial.	1st Trial.	2nd Trial.	3rd Trial.	4th Trial.	1st Trial.	2nd Trial.	1st Trial.	2nd Trial.	3rd Trial.
¼	..	..	..	..	..	..	..	..	1¼	..	Pile bent 1⅛″ at ground level.	Pile bent 1⅛″, which caused amount of forward movement to vary.
	..	..	..	⅛	..	..	..	..	,,	..		..
..	..	..	..	..	..	..	..	..	,,	..		..
	..	..	..	¼	..	..	..	..	1⅜	⅛		..
	..	..	..		⅜	..	..	½	1½	,,		
	..	..	..			..	..	..	2	,,		
	..	5¼	..			..	..	..	2¼	,,		
1½	..	..	..			..	..	1¼	2½	,,		
1⅞	2⅞	5⅝	..	..	1	..	..	1½	2⅝	,,		
..	3¼	6¼	..	..	1¼	..	..	1¾	3¼	,,		
..	5¼	..	8½	..	1½	..	..	2½	3½	,,		
..	6½	..	..	..	..	..	..	..	..	,,		
..	..	7¼	9½	..	1⅝	2½	..	2⅝	4⅛	,,		
..	..	8¾	..	..	..	..	..	..	..	,,		
..	..	..	10	..	1⅝	..	..	With 13 tons stress the pile broke off at about 5′ below the ground level.		⅛		
..	..	..	12	..	..	..	..			..		
After 13½ tons the pile yielded so much that no more stress could be applied.				..	1⅞	2⅝	..			..		
				..	2¼	2¾	3⅛			..		
				..	2½	2⅞	..			..		
				..	2¾	3	3¼			..		
				..	..	3¼	3⅜		..	..		
				..	..	..	3⅝		..	..		
				..	..	..	4		..	..		
..				When stress reached 20 tons it was removed, and the pile resiliated 1¼″.						..		
										No more stress could be registered by machine.		

(*Paper No. 1672.*)

"The River Thames."[1]

By JOHN BALDRY REDMAN, M. Inst. C.E.

A COMPARISON of the tides, registered at Sheerness and at the old or upper Shadwell entrance of the London Docks, shows a continuous increase in range in the Port of London, and is so remarkable as to deserve special record. This growing tidal action is illustrated by the increased differences between the high waters and low waters at the two stations.

The maximum high-water difference hitherto recorded was 6 feet 4 inches on the 27th of February, 1874[2], but on the 17th of April, 1877, a difference of 6 feet 11 inches occurred, due to a gale from E. to E.N.E. on that and the preceding days. Many tides of that year gave an excess of elevation amounting to more than 5 feet in London; several also in 1878.[3] The low-water differences are quite as remarkable, showing how pronounced and accentuated is now the metropolitan tidal action. On the 14th of November, 1840, with a W.S.W. gale, low water in London was 3 feet 11 inches lower than at Sheerness. On the 24th of December, 1877, with a west gale, the low water was 4 feet 4 inches lower than at Sheerness, and other tides with westerly gales at the end of this year gave lower low water in London by 2 feet to 3 feet 5 inches. On the 27th of January, 1877, a difference of 3 feet 9 inches occurred with a neap tide and W.N.W. gale; and with westerly gales many tides during this year were at low water 2 feet 2 inches to 3 feet 5 inches lower in London. In November and December, 1878, with neap tides and W.N.W. winds, there were differences of from 2 feet 10 inches to 3 feet 4 inches in favour of London. The greatest low-water difference in favour of Sheerness, *i.e.* lower, was on the 2nd of March, 1877, being 2 feet 1 inch, and in August, 1873, and in February, 1874, amounting to 2 feet 5 inches.[4]

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[1] Abstract by the Author of a supplement to a former communication on the same subject. *Vide* Minutes of Proceedings Inst. C.E., vol. xlix., pp. 67-114.

[2] *Vide* Minutes of Proceedings Inst. C.E., vol. xlix., p. 108.

[3] April 4th, 1840, 5 feet.

[4] Feb. 27th, 1838, and Feb. 18th, 1840, 2 feet 2 inches.

In proof of the increased tidal range in the Metropolis, on the 21st of January, 1878, the tide ebbed down to 23 feet 2 inches below Trinity high water, with a S.W. gale, or lower than was ever before recorded. But the number of ebbs below 20 feet under Trinity high water have marvellously increased, as will be seen by the annexed table, due no doubt in a great measure to the removal of shoals in the lower reaches of the river. The low ebbs are usually accompanied by westerly gales. The result is, that the mean high water of the year is now within 9 inches or 10 inches of Trinity high water. High water of an ordinary spring tide is now 10 inches or 12 inches higher, an equinoctial spring tide 2 feet higher, and abnormal tides, due to northerly gales during the equinoxes with heavy land floods, have attained to 4 feet and 4 feet 6 inches above that datum, or 9 inches in excess of any previously recorded. The wind frequently also accompanies the tide around the British Isles, making the circuit with the ocean current, a S.W. wind blowing up the English and Irish Channels and a north wind down the North Sea. This may often be seen by reference to the daily weather charts of the Meteorological Committee. The heights calculated by the Admiralty authorities and the actual range of the tides closely approximate, except when affected by wind, and differences of 3 feet to 3 feet 3 inches will occur at times in excess with N.W. winds. The tide is sometimes checked, and loses from 1 foot 3 inches to 3 feet 2 inches of its computed range with westerly gales. From these causes differences in range of two successive tides occur, amounting to from 3 feet to 7 feet.

Spring tides, from their greater volume, when differing from the Admiralty forecast, are usually in excess from the effect of gales of wind, the greatest influence being exercised by those from N. to N.W. Neap tides, from their reduced volume, feel less such disturbing causes, and are as often short of the estimated height as above it.

The mean low water of the entire year is now 1 inch lower than any analysis shows for forty-five years, and the high water of the entire year is now nearly 3 inches higher than any year prior to 1875.

The average increased elevation of high water in London as compared with Sheerness is now higher by from 4 inches to 5 inches than the average difference from 1833 to 1845.

The effect of wind at times appears anomalous; but an examination of the daily weather charts of the Meteorological Committee shows plainly enough the causes of variation.

THAMES TIDES. ABSTRACT of EXTREME EBBS EXCEEDING 20 feet BELOW TRINITY STANDARD.

Sheerness.						London Docks.					
Year.	Total Number of Ebbs exceeding 20 Feet below Trinity Standard, and Dates of Lowest.	Below Trinity Standard +20 Feet.		Trinity Standard 11 ft. 3 ins. above zero. Below zero of Tide Gauge +8 ft. 9 ins.		Year.	Total Number of Ebbs + 20 Feet below Trinity Standard, and Dates of Lowest.	Trinity Standard on Tide Gauge 25 ft. 4 ins. Below Trinity Standard.		Above zero of Tide Gauge.	
		Feet.	Ins.	Feet.	Ins.			Feet.	Ins.	Ft.	Ins.
1833	122 Oct. 14th, A.M.	22	1	10	10	1833	8 Aug. 31st, A.M.	21	4	4	0
1834	112 Feb. 26th, A.M.	22	6	11	3	1834	21 Feb. 26th, A.M. Mar. 1st, P.M. Nov. 5th, A.M.	21	1	4	3
1835	78[1] Feb. 17th and 18th, A.M. Apr. 14th, A.M.	21	8	10	5	1835	12 Feb. 23rd, P.M.	20	10	4	6
1836	94[1] Jan. 23rd, A.M.	22	6	11	3	1836	17 Jan. 23rd, P.M.	21	7	3	9
1837	79[1] Feb. 7th, A.M.	22	5	11	2	1837	27 Jan. 9th, A.M.	21	1	4	3
1838	97 Mar. 27th, A.M.	22	2	10	11	1838	26 Oct. 19th, A.M.	20	10	4	6
1839	81 Feb. 16th, A.M.	22	2	10	11	1839	24 Mar. 15th, A.M.	22	2	3	2
1840	71 Feb. 10th, A.M.	21	1	9	10	1840	26 Aug. 18th, P.M.	21	4	4	0
1841	51 Dec. 15th, P.M.	21	3	10	0	1841	24 Jan. 10th, P.M. Oct. 18th, A.M.	21	4	4	0
1842	34[1] Feb. 10th, P.M.	22	10	11	7	1842	25 Jan. 27th, A.M.	21	8	3	8
1843	35[1] Mar. 17th, A.M.	22	9	11	6	1843	34 Oct. 28th, P.M.	22	5	2	11
1873	85 Sept. 9th, A.M.	20	9	9	6	1873	69 Apr. 28th, A.M.	20	11	4	5
1874	118 Mar. 21st, A.M.	21	9	10	6	1874	85 Aug. 31st, A.M.	21	9	3	7
1875	62 Feb. and June	20	6	9	3	1875	58 Mar. 22nd	20	10	4	6
1876	66 Apr. 25th, P.M.	21	0	9	9	1876	46 Feb. 13th, A.M.	21	4	4	[illegible]
1877	95[2] Mar. 2nd, A.M.	22	9	11	6	1877	43 Dec. 24th, P.M.	22	0	3	[illegible]
1878	78 Jan. 21st, A.M. Sept. 15th, P.M.	22 22	7 8	11 11	4 5	1878	53 Jan. 21st, A.M.	23	2	2	[illegible]

[1] Ebbs affected (reduced in number) by the gathering of the mud grounding the float. Day tides [illegible] registered at the London Docks.

[2] In this year the month of June was only registered for the two first days, the tide gauge being u[illegible] repair, so that No. 95 is for eleven months only. N.B.—Applies to Sheerness only.

N.B.—These tables show that from 1833 to 1839 there was a very small proportion of ebbs below 20 feet under Trinity in the Port of London as compared with those at sea. But from 1840 to 1843 inclusive this proportion considerably increased. This increase is still more manifest from 1873 to 1878 inclusive. In fact the proportion is now reversed, *i.e.*, whereas formerly there were a much fewer number of low ebbs in London as compared with those at sea, now there are a much greater number, showing how much the low water is lowered in London, and how much lower at times it is than at sea.

MEMOIRS OF DECEASED MEMBERS.

Mr. JOHN FREDERICK BOURNE was born on the 24th of May, 1816. He was the eldest son of John Henry Bourne, Lieutenant, 2nd Dragoon Guards, and subsequently an agriculturist on the family estate at Dalby, Lincolnshire. His education was commenced at Spilsby grammar school, under the Rev. Isaac Russell, and completed at Mill Hill school. In 1831 he was articled to five of the original directors and promoters of the Liverpool and Manchester railway, in Liverpool, and was employed by them in various office duties connected with that and other lines. He then entered into partnership with a Mr. Bartley, in Manchester, where, in 1838, he invented and patented a wrought-iron railway wheel, afterwards known as "Chambers' wheel." Taking holy orders, Mr. Bourne next was for some years in clerical charge of a parish in Demerara; but, under the influence of conscientious convictions, he threw up this preferment, and left the colony to indulge his taste for civil engineering, which he had always felt would be a more congenial vocation. He was afterwards employed on the Burlington and Missouri rivers, and the Iowa and other railways, in the United States, and also paid a visit to Canada. From North America Mr. Bourne returned to Demerara, and in 1854 was appointed Civil Engineer and Superintendent of Public Works in the colony of British Guiana. One of his most important achievements was the construction of the sea-defences of Georgetown, the capital. Up to the year 1855 these had been in charge of the Royal Engineers of the neighbouring garrison, and the practice had been to obtain from the penal settlement, and other places, loads of rubble granite and deposit them in front of the parapets, where they gradually subsided into the mud, requiring constantly to be replaced. In the month of February of that year, however, the dams gave way and the whole suburb of Kingston was flooded by the sea. This led to the abandonment of the sea defences by the Imperial Government, and their transfer to the Colony. Mr. Bourne then commenced the construction of a solid mass of masonry on an inclined plane from

the dams, combined with groynes at frequent intervals, and this plan has been continued and extended ever since with great, if not absolute, success. He visited Europe professionally to study plans in Holland and in Lincolnshire for sea defences, furnishing detailed reports on his return to the Colony. A scheme prepared by him for better supplying Georgetown with water and for improving the system of drainage was, owing chiefly to its costliness, never carried out. Amongst other works, designed and constructed by Mr. Bourne in Demerara, may be mentioned the parish church of St. Paul's, and the Assembly Rooms and Almshouses in Georgetown. He also organised and commanded a corps of Militia Artillery.

In 1863 Mr. Bourne was appointed Inspector-General of Railways, and Colonial Railway Engineer, Cape of Good Hope, by the Governor, Sir Philip Wodehouse, a position which he occupied till 1867. Plans and surveys were drawn out by him, and a small portion of the work executed. While still acting in his capacity as Colonial Railway Engineer, Mr. Bourne proposed a plan to reconstruct the Roman Rock lighthouse, situated at the entrance to Simon's Bay, which had been previously condemned as unsafe. His design was accepted, and executed by the resident engineer, Mr. W. Fairbairn King, under Mr. Bourne's superintendence.[1] The drawings and description of an invention made about this time, of a compass without magnetism, were issued under the name of a "Whirl Wheel Star Pointer," in the 'Mechanics' Magazine' for April 9th, 1869. In the autumn of the previous year, Mr. Bourne was commissioned by H.M. Government to visit the West Coast of Africa, with the object of preparing reports as to the best means of carrying out a system of drainage at Gambia, and of constructing a dry dock at Sierra Leone. On his return to England he was appointed Superintendent of Public Works at Barbados in 1869, and after remaining there for two years [illegible] removed to the Island of Trinidad, to take charge of the sug[illegible] estates belonging to the Colonial Company, Limited. Here [illegible] was appointed member of the Legislative Council in March 18[illegible] The large reservoirs, designed and carried out by him for t[illegible] supply of water to the sugar factory of the company, were [illegible] complete success. In the summer of 1877, Mr. Bourne came [illegible] England on leave of absence, returning to Trinidad in Decembe[illegible] and on the termination of his agreement with the Colon[illegible] Company, in June 1879, he was re-appointed to his old p[illegible]

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxviii., p. 49.

of Superintendent of Public Works at Barbados, where his hequered and eventful career was cut short by paralysis on the 27th of October, 1879.

The following is extracted from a letter received from a friend who had been acquainted with Mr. Bourne for over thirty years:—"Mr. Bourne was a man of singular simplicity and straightforwardness of character, combined with a most amiable and cheerful temperament. As a matter of course, his conduct of the department of Public Works (in Demerara) was exposed to much adverse criticism, but I never saw him ruffled or out of temper. In private life he was a most pleasant and intelligent associate, and those who knew him best will feel his loss the most keenly."

Mr. Bourne was elected a Member of the Institution of Civil Engineers on the 2nd of April, 1867.

MR. GEORGE HARDINGE was born in Dublin on the 20th of January, 1831. He was the son of the late Mr. W. H. Hardinge, a well-known Irish barrister, and Deputy Keeper of the Records in Ireland. He was educated at Mr. Flynn's school, where at an early age he distinguished himself in mathematical studies. In October 1849 he entered Trinity College, and took his B.A. degree in 1855, and proceeded to M.A. in 1862. In August 1853, he bound himself for three years as an articled pupil to the late Mr. Sampson Lloyd, of the firm of Lloyd, Foster and Co., of Wednesbury. He then became a pupil of Captain W. S. Moorsom, M. Inst. C.E., till 1857, under whom he was subsequently employed for a few months on the St. George's harbour, railway, and pier; and also had charge of the formation of approaches to river wharves near Chatham.

In the beginning of 1858 he entered the service of the Bombay and Baroda railway company as an assistant engineer. During a three years' engagement with that company he was employed on surveys and in superintending the construction of portions of the line; among others, a section of 20 miles, from Meagama to Baroda, and another of 25 miles, from Meagama to Broach. At one time he had upwards of 40 miles under his charge, including large viaducts and other important works, the whole being carried on without contractors. These experiences proved

very valuable to him in conducting similar works in other parts of India in later years. During one of his early surveys near Baroda he was surprised and narrowly escaped capture by Tantia Topee and his army of mutineers, and had to flee for his life. His health having suffered from the climate, he threw up this appointment in 1861. On returning to England he became assistant to Mr. A. W. Forde, M. Inst. C.E., who had just then retired from the position of Chief Engineer in India for the Bombay and Baroda railway, and was starting a private practice in London, and under whom, in 1861-2, he developed a scheme for tramways in India. From January to September 1863 he was assistant to Mr. J. G. B. Marshall, M.A., surveyor to the district of West Ham, in the east end of London, and gained experience in all kinds of modern town improvements, such as buildings, roads, bridges, sewers and other sanitary works.

In the autumn of 1863 he went to Madras as resident engineer to the Indian Tramways Company, and proceeded with the laying out and construction of a line 20 miles in length, between Arconum and Conjeveram, near Madras. He resigned this appointment in July 1864, and in November of that year accepted an engagement with the Madras Railway Company as a second class engineer. He was promoted to first class on the 4th of February, 1869, and remained in the service of the company, holding this rank, till his death. For a short period in 1871 he acted as deputy chief engineer of the open line. During the whole of his engagement on the Madras railway he reported direct to the Chief Engineer in India. At first he had charge of the Raichore survey, 150 miles in length; then he was entrusted with the construction of 10 miles of the north-west line; next he had charge of the permanent way of the third and fourth divisions of the open portions of the south-west line, 200 miles in length; and afterwards he had the control of the Cochin survey, from Puttamby to Cochin, 64 miles in length. From March 1868 to September 1871 he was engaged in the construction of the new central station at Madras, which important work he executed without the intervention of contractors. During the same time he was in charge of the extensive terminal works and buildings at Reyapooram, the large buildings in connection with the goods station at Madras and the locomotive shops at Perambore, and he superintended the carrying out of an important contract by Messrs. Hopkins, Gilkes & Co. for the conversion of old rail chairs into cast-iron bowl sleepers. He next had charge of the permanent way of a division of the south-west line, and was frequently complimented upon the admirable

manner in which the road was kept. In March 1877 he proceeded to England on sick certificate, and hoped during the extended leave then granted that his health, which had suffered much from the effects of the Indian climate might be completely restored. However, the good results of his furlough were but temporary. He returned to India in November 1878, and was appointed resident at Bangalore, but the following hot season soon told upon him, and he died in Madras of abscess of the liver on the 19th of September, 1879.

Mr. Hardinge was elected an Associate of the Institution of Civil Engineers on the 3rd of December, 1861; and was transferred to the class of Member on the 29th of October, 1872. He was highly esteemed for his professional abilities. His great originality of thought and expression, allied to considerable culture, made him a most amusing companion, and his personal character greatly endeared him to his friends.

LIEUT.-COL. JOHN PITT KENNEDY was the fourth son of the Rev. John Pitt Kennedy, Rector of Carn Donagh, County Donegal, and afterwards Rector of Baltoagh in the county of Londonderry. He was born at Donagh, County Donegal, on the 8th of May, 1796, and died on the 28th of June, 1879. His early education was received at Foyle College, Londonderry, under the Rev. James Knox. In the year 1812 he entered the Royal Military Academy, Woolwich, and in the summer of 1815 passed out, having taken the fourth place, for the Corps of Royal Engineers. His first service in the corps was for a period of six months upon the Ordnance Survey in Gloucestershire and Oxfordshire. He did regimental duty for a considerable time, and for a portion of that period had charge of a company. In the year 1819 he was ordered to Malta, and thence to Corfu. On the 6th of April, 1820, he was appointed to the immediate direction of the works going on at Santa Maura, and on arrival there found the island in a state of insurrection, which was suppressed in a few days. The principal works in progress were: a moat to form an artificial harbour on the eastern side of the island, and a canal through a shallow inlet of the sea, to admit boats from the new eastern harbour to the town, and to the natural harbour westward of the island. He was occupied about two years in constructing these works, when a reduction of the Corps of Engineers placed him upon half-pay.

He was then asked by the Government to retain his civil appointment as Chief Engineer of the public works in progress, but he refused. On arriving in England, in 1822, he was invited by Sir Charles Napier to return to the Ionian Islands, as his Secretary and Director of Public Works in the Island of Cephalonia. He accepted the appointment, but was only able to do so by getting transferred into the line as a captain. Amongst the works designed and executed by him were the Guardianno lighthouse, a Doric column, 12 feet in diameter at the base, and 85 feet high—which cost only £723, exclusive of the lantern; the lighthouse at Point Theodore, the columns of which are twenty-four in number and about 8 feet high, the height to the top of the lantern being 30 feet; and a marine parade, quay, and market buildings. He also intersected the island with roads. When placed on half-pay, in 1830, he removed to Ireland, where he was surrounded by so much misery that he was induced, on public grounds, to sell his commission as captain, in order to provide funds to establish an industrial school at Lough Ash, County Tyrone. The principle which he thus tested has been since adopted by the Government, and extended with much public advantage. In 1838 he joined the National Educational Department, Ireland, as Inspector-General, on the understanding that practical instruction in agriculture was to become a prominent branch in the national teaching, as urged in a book written by him, entitled "Instruct, employ; don't hang them." The first act of the Board, after his joining, was to appoint an inspector of schools for each county. These officers were chosen by public examination from several hundred competitors. He then selected 60 acres of land at Glasnevin, on the northern outskirts of Dublin, with a large house and garden in the village, as the site for a central model farm and training establishment for teachers coming from the district schools. The teachers likewise attended daily at Marlboro' Street, Dublin, for instruction and training in the method of teaching. This system is still in operation at Glasnevin. Subordinate to this first-class central agricultural training school, his plan was to have a second-class agricultural school at the centre of each of the four provinces, a third-class agricultural school at the centre of each of the thirty-two counties, a fourth-class agricultural school at the centre of each barony, and a fifth-class agricultural branch connected with each of the existing elementary schools. Had this general arrangement been fully carried out, Ireland, as regards agricultural instruction and useful knowledge, might now have been a model to other nations.

In the year 1843 he was appointed secretary to a Royal Commission for inquiring into the state "of the law and practice in respect to the occupation of land in Ireland, &c." The result of this investigation, which was very arduous, was printed in several large volumes. In 1846 the late Lord Devon appointed him agent to his extensive estates in the County Limerick. Here he carried out the same principles of estate management that he had so successfully practised at Lough Ash and Cloghan.

The failure of the potato crop having caused an extensive famine in Ireland, in the year 1847, he was invited by the late Sir Robert Peel to take the office of secretary to the Relief Commission which was then established. Passing through Dublin in the spring of 1848, Captain Kennedy found the city, and the country generally, in a most excited state, and a revolutionary outbreak in the streets daily expected. Numerous clubs, on one side, were holding nightly meetings for the immediate organisation of an active rebellion; defence committees, on the other hand, were in constant deliberation upon measures for the preservation of peace and order and for the protection of life and property. He attended some of the latter, and found them without any sound principles of action. He convinced them that instead of limiting their efforts to the defence of each separate house by its own inhabitants, they should select a few commanding points which, being properly occupied, would defend the entire district. Both the inhabitants and the public authorities, civil and military, concurred in this view. He was furnished with the best existing plans of Dublin, and he divided the city into defence districts, marking on the maps the various points in each, the defence of which would thoroughly protect the whole. In a few days he had the work done so completely that by throwing a few armed men into each of the selected parts in the various districts when the necessity should arise, every street and lane in Dublin would be enfiladed or exposed to the fire directed from one or more of those defence posts. The number of volunteers for occupying each of these small posts was settled at six, to be relieved every morning. In addition to the numerous small posts there were to be twelve main posts, distributed at convenient localities, each to be manned by at least three hundred armed volunteers, relieved daily, whose duty it would be to furnish patrols and to reinforce where necessary the minor posts. A large body of volunteers was in readiness to turn out for duty. He was furnished with authority to take possession of any house fixed upon for a post if the city were proclaimed. The general arrangements

being thus made, matters went on with increasing excitement from day to day. When the old Orange party thought that such a crisis had occurred as would sustain them in making the Government restore some of their class privileges, which had been gradually reduced during the previous quarter of a century, they sought, in return for their support, either to be acknowledged by the Government as Orangemen, or to have arms granted them, failing one of which privileges they threatened to pass a resolution at their lodges withholding their support from Government. When this request was laid before the Lord-Lieutenant (Lord Clarendon), by a deputation of Orangemen, they were informed that he could not act as they desired; but that as Captain Kennedy was taking a leading part in the volunteer defence of the city, it was possible he might find means for furnishing them with arms. He did so, authorising them to order five hundred stand of arms at a price not exceeding £1 5*s.* each. They went off perfectly satisfied, and that night, at meetings of their lodges, they reported the circumstances, and passed loyal resolutions declaring the determination of the Orangemen to sustain to the utmost the Government in the defence of law and order. This Orange declaration of loyalty exercised a most beneficial effect upon the crisis. Captain Kennedy failed to raise the amount required to pay for the five hundred stand of arms by subscription, and disbursed their cost out of his own pocket. He incurred this, to him, serious expense *pro bono publico*, although by his action wholesale bloodshed was no doubt prevented in Dublin.

On the occurrence of the Indian crisis of 1849, Sir Charles Napier was appointed Commander-in-chief in India, and he invited Captain Kennedy to accompany him as military secretary. The Duke of Wellington recommended Her Majesty to permit Captain Kennedy to re-enter the army as an ensign, with the brevet rank of major in India, with an understanding that he should soon be advanced to the rank of lieutenant-colonel. Major Kennedy, with Sir Charles Napier's sanction, offered to devote as much time as his duties of military secretary would permit, to superintend gratuitously the laying out and construction of a military road from the plains of India to Simla, extending it through the Himalaya mountains northward, and Sir C. Napier allowed the assistance of a company of Sappers, which was placed under his orders for this work. The Governor-General, Lord Dalhousie, gladly accepted the offer, removing all the usual forms, and granting Major Kennedy full discretionary power as to the course he might adopt for accomplishing the object in view. His

labours were crowned with success, and were instrumental in introducing to India a new principle for the construction of that class of public works, which, whilst it adds to the quality and rapidity of the work, reduces its cost to about one-eighth of the former Indian rate, or £130 per mile against £1,267 per mile. At the request of the Government, he furnished a statement of the rules and principles upon which he conducted this work, which were printed and circulated for general adoption in the North-western Provinces. A feature of considerable importance in the superintendence related to the employment of the Sappers, who were engaged entirely as overseers of large working parties, instead of merely as individual labourers. He was thus able to provide an ample, well-disciplined staff of efficient overseers. On Sir C. Napier leaving Simla to return to England, Major Kennedy proceeded to Calcutta to take charge of the railway department, as consulting engineer to Government. Here ample scope existed for his genius and powers of organisation. He laid down plans for the application of a system of railroads throughout India, and propounded the axiom that every mile of rail opened would enable the Government to dispense with a company of soldiers, whilst it tended to enrich the inhabitants by developing mines of wealth at the time unthought of. However, his health unfortunately suffered from the climate, and after a year's discharge of the office of consulting engineer, he was obliged to return to Europe and to resign this appointment.

In 1852 he was introduced in London to Lieutenant-Colonel French, who had been Acting Resident at the Court of the Guicowar of Baroda. Colonel French wanted to get up a company to construct a line of railway from Baroda to Tankaria Bunda, in the gulf of Cambay, a distance of about 45 miles. Colonel Kennedy joined him, but instead of the original line proposed, they projected what is now the Bombay, Baroda, and Central India railway. Their object was to open the most effectual line of intercourse from Bombay, through the central and north-western districts, to meet the railway in progress of construction from Calcutta to Delhi, together with all the branches that such a line could require. Upon the formation of the company, Colonel Kennedy was appointed consulting engineer and managing director. A staff of engineers was sent to Bombay, and during the cold season of 1853, comparative surveys, sufficient to lay a well-digested scheme before the Government, were made. On the 3rd of November, 1854, the Governor-General, Lord Dalhousie, sanctioned the immediate construction of the line from Bombay *viâ* Surat,

Broach, and Baroda, to Ahmedabad, leaving the remainder of the scheme for future decision, and the work to be commenced at Bombay. The Home Government, however, decided that the work should be commenced at Surat. The main line from Bombay to Ahmedabad is 308 miles in length, and crosses several large rivers and inlets of the sea. It runs through a flat, alluvial district, and the only difficulty to be encountered in its construction was the erection of the necessary bridges. So great did this appear, that some engineers connected with the Bombay Presidency stated that these arms of the sea and large rivers could not be bridged, except at such a cost as would render the construction of the railway unjustifiable. Knowing that masonry structures would be extremely expensive, Lieutenant-Colonel Kennedy had the foresight to turn to practical account the late Mr. Mitchell's invention of the screw-pile, and the rivers were bridged by Mitchell's screw-piles and Warren girders. He was a strong opponent to the break of railway gauge, and did all in his power to dissuade the Indian Government from adopting it.

He wrote many pamphlets on Indian subjects. The following extract is from the report of the Bombay, Baroda, and Central India Railway Company, of the 20th of June, 1879: "The Directors announce, with deep regret, that failing health has obliged Colonel John Pitt Kennedy, the consulting engineer, and one of the original founders of the Company, to resign his appointment. The Directors cannot express in more fitting terms their sense of Colonel Kennedy's high qualities, than by adopting the following resolution of the Bombay Government: 'In resigning the post of consulting engineer to the Baroda Railway Company, Colonel Pitt Kennedy terminates a long career of public usefulness, during which his ability, integrity, and courtesy, have gained him the respect and esteem of all with whom he has been brought in contact. Government desire to take this opportunity of placing on record their sense of his personal worth, and of the value of the services he has rendered to the State.'"

He was elected a Member of the Institution of Civil Engineers on the 3rd of March, 1868, and occasionally took part in the discussions at the evening meetings.

MR. JOHN PENN was born at Greenwich in 1805, and died at the Cedars, Lee, in 1878. He thus lived during the most important part of the nineteenth century. How much he accomplished

during his lifetime, the following memoir will very briefly show.

He was emphatically well born. His father was a man of great mechanical genius; industrious, persevering, and always working his way upwards and to the front. Beginning as apprentice to a millwright at Bridgewater, the elder Penn was made foreman of an important work at Bristol when he was only twenty-two years of age. He became celebrated for his theoretical and practical knowledge of the teeth of wheels,—a branch of construction which was then imperfectly understood by mechanicians. Leaving Bristol in 1793, he made his way to London, where he remained ever after. He began business on his own account at Greenwich in 1799, where he soon became known as a millwright. It may be noted that many of the principal civil engineers began life as millwrights,—such as Brindley, Rennie, Sir William Fairbairn, Sir William Cubitt, and others. The treadmill for prisons, designed by Cubitt in 1818, was first executed at Mr. Penn's works. But his greatest attention was devoted to flour mills, in which he made many improvements, particularly in the substitution of metal for wood framing. In consequence of a strike amongst the millwrights, who then constituted a powerful society, Mr. Penn was induced to adopt self-acting tools, which greatly improved the uniformity of the work turned out, and also led to the employment of another class of workmen. Steam-engine making was introduced to the factory; and in his hands, and especially in those of his son, the marine engine was subjected to many important improvements.

Under such a father was the late Mr. John Penn brought up. He received the usual education, but his most important school was the workshop. He learnt the use of his hands, and he worked steadily and perseveringly. He learnt to handle the file; and the use of the file, before self-acting tools were in general use, was a great mechanical accomplishment. He worked at the forge, and could handle the hammer with any man in the smithy. He worked at the lathe, and turned out beautiful work. In short, he was a thoroughly skilled workman, and a master who is becoming very rare in these days; for he could take the tools out of any man's hands, and deftly show how the work should be done—the true method of securing the workman's respect and admiration.

He was very intimate with Joseph Clement, a man of great mechanical merit. Clement improved the lathe, which he made

self-regulating; and he established a mechanical practice with regard to the pitch of the screw, which has now become universal. He also invented the headless tap, which, in the opinion of Nasmyth, "ought to immortalise him among mechanics." His planing machine was also one of the wonders of the time. He modified it so as to present a complete union of the lathe with the planing machine and dividing engine, by which turning of the most complicated kind was readily executed. Mr. Penn carefully studied the work going on in Clement's workshops, and he afterwards became one of his best customers. To the day of his death, he always spoke of Clement as one of the most ingenious mechanics whom he had ever known.

The elder Penn died in 1843; but, for several years before that event, his son had had the entire management of the works. The first engine introduced by him was the well-known "grasshopper." A 6 HP. engine of that type drove the machinery of his workshop. It was a small beginning, but it led to many greater things. Some time after, Mr. Penn designed a table engine with a 10-inch vertical cylinder, which answered admirably; and it is still in use at the Greenwich works.

To improve himself in the knowledge of machinery, Mr. Penn visited by turns all the more important establishments in England and in Scotland. He also determined to see what the foreigners were doing; and he made special journeys into Belgium, Holland, Germany, France, Switzerland, and Italy, for this particular purpose. He brought back many "wrinkles," which he embodied in his own works. Mr. Penn was bent on having the best of everything, no matter where it came from. He required to have perfect tools and perfect machinery. Thus his success was not the result of chance, but of faithful and persevering work. He had the seeing eye and the observant mind. He shirked nothing—labour, pains, nor application. He would have no shoddy work. Everything must be turned out in the best manner. He would trust to no underhand information. He trusted himself—his own eyes, his own hands, his own faculties. His great undertaking centred in himself.

When Mr. Jacob Perkins invented the steam-gun, the work was sent to Greenwich to be executed. John Penn was then only twenty-one; but he undertook to make the gun. It had a wrought-iron rifled barrel of 3 inches calibre. The steam-gun was finished, and answered admirably. Although it had been made to the order of the French Government, it was taken to a piece of

waste ground in Westminster to exhibit its wonderful powers, in sight of many military men who were invited to inspect it. One day the Duke of Wellington came to inspect the steam-gun. Great things were expected from the Duke's visit. John Penn was there to show it off. Everything was done in order; the gun, by the aid of steam, shot off its 3-inch bullets with inconceivable rapidity, penetrating an iron plate 100 yards off. Then the Duke began to put his questions to Penn. "Now, my young man," he said, "what weight is the boiler?" "About 5 tons," said Penn. The Duke shook his head. "Ah!" he said, "if we had been fighting with steam-guns till now, what a grand thing we should have thought the invention of gunpowder!" The Duke departed, with the same grave wag of his head. Penn immediately went to Perkins, and said, "It's all up with us now." He told him what the Duke had said. The result was, that the Duke made an unfavourable report on the gun—not so much as regarded its performances, but as to its unwieldy weight while travelling across country or in the field. The Duke thought better of Penn than of the gun which he had exhibited. He formed a favourable opinion of him, and afterwards found many opportunities of testifying his high admiration of the young engineer. After the trial in London, the gun was sent to France, and Mr. Penn went with it. He remained in Paris for about three months, to erect it and put it in operation. Nothing came of the invention. The revolution of 1830 swept away Charles X. and his steam-gun. It was afterwards brought back to England, and exhibited at the Adelaide Gallery, until the Exhibition was dispersed. It was probably afterwards sold as old iron.

Mr. Penn devoted the principal part of his life to the manufacture and improvement of marine engines. As early as 1823, he repaired the engines of a vessel called the "Nero," and fitted her up with new boilers in the following year. The first marine engines which he made at Greenwich were for the steamer "Ipswich," in 1825. He was then only in his twentieth year. This vessel gave such satisfaction that it was followed by the "Suffolk," employed in the same trade. These vessels ran from London to Ipswich along the east coast, and up the river Orwell. They were fitted with beam engines of 40 HP.

Steam-boats were by this time regularly running on the Thames, and Mr. Penn had his fair share of the trade of fitting them with engines. Whatever he undertook he endeavoured to improve; and in this he was greatly helped by the workmen in his estab-

lishment. He himself took a special interest in training the boys, so that they might become first-class workmen. He gave a great deal of time to them; showed them how they should handle the file, how they should use the hammer, how they should work at the lathe. He did this in so kindly, and yet in so masterful a manner, that they never forgot his instructions. Mr. Penn was particularly proud of the excellent work obtained from his boy workmen.

By the year 1845, four passenger steamboats, running between London and Greenwich, were fitted by him with beam engines of 45 HP. In 1838, he began to make marine engines with oscillating cylinders. The oscillating engine was invented by that gifted mechanic, William Murdoch, in 1785. It was afterwards patented by Aaron Manby in 1816. The oscillating system was at first regarded with prejudice; until Mr. Penn, feeling convinced that there was a good principle involved in the idea, grappled with the difficulties, and eventually brought the engine into favour. The first paddle-boats with machinery of this construction plied between London and Richmond. They had engines of 24 HP. and tubular boilers, and the results were extremely satisfactory.

At length, the Lords of the Admiralty took up the application of steam power to ships of war. Naval officers, who had grown old in the tactics of sailing ships, could not brook the idea of employing the artificial power. But at length they began to try steam power, first hiring tugs belonging to private owners, and then using a small tug of their own. "The Comet" was built in 1822, after the designs of the late Mr. Oliver Lang. Yet this vessel was only employed in towing ships of war from one naval seaport to another.

But when they saw the steamers fitted with Mr. Penn's engines scudding up and down the Thames, and more especially when they found the French anticipating them in the use of the new motor in ships of war, their antipathy abated. In 1844, the Admiralty employed Mr. Penn to remodel the engines on board the "Black Eagle." The ship had been formerly provided with beam engines of 131 HP. It was a slow and lumbering ship—so slow and lumbering that, in 1838, a paddle-boat steamer from Rotterdam passed her rapidly at the mouth of the Thames, and soon left her far in the distance. But when Mr. Penn's oscillating engines replaced the old steam gear in 1844, the "Black Eagle" became a handy, steady, and rapid ship. He introduced in the same space oscillating engines of double the power, with tubular boilers;

thus securing the more rapid production of steam, a much greater speed, and a large saving in coal. Mr. Penn made a voyage in this ship, and carefully watched the action of the engines. He was satisfied that he had already made a great stride in the working of ships of war.

This was the beginning of Mr. Penn's employment by the Admiralty; and it led to numerous orders for marine engines. Among the most celebrated ships with oscillating engines may be mentioned, Her Majesty's yacht "Victoria and Albert," the Emperor of Austria's yacht "Miramai," the Sultan's yacht "Taliah," the "Mahrousseh" of Egyptian fame, with a speed of 18½ knots; as well as a large number of fast passenger steamers plying between England and the continent.

But it was only when the paddle was supplemented by the screw that Mr. Penn began to supply the greater part of his engines to the Royal Navy. In 1843, he was commissioned to make oscillating engines for the "Phœnix," of 260 HP.; and in the following year for the royal yacht "The Fairy," of 120 HP., which was employed as a tender to the "Victoria and Albert," which lay off Woolwich. The "Phœnix" and "Fairy" were modelled after the "Archimedes," the vessel which first embodied Sir Francis Pettit Smith's invention of the screw propeller. The "Archimedes" had steamed round the British Islands, and made a voyage across the Bay of Biscay to Oporto. The results were so satisfactory that Mr. Brunel obtained the loan of the vessel, and made various experiments upon her with screws of different pitches.

Mr. Brunel had originally designed the "Great Britain" to be worked by paddles, and the wheels were actually in course of construction. But when he ascertained the results of the screw system, he altered his designs for the purpose of adopting that propeller. The "Great Britain" was launched in 1843, but it was not until some years later that Mr. Penn constructed her engines of 500 HP. on the oscillating principle. The screw, however, was not as yet driven direct, but through gearing. This proved entirely satisfactory as regards speed; indeed too satisfactory, as the vessel was run on shore in Dundrum Bay on the North of Ireland, the accident being due in some measure to her excessive speed as compared with the steam vessels of those days.

The screw had been adopted in many merchant vessels. The reports of the Admiralty surveyors were entirely in favour of this method of propelling ships; and at length the Admiralty resolved upon its general adoption. This again put Mr. Penn on his mettle.

Although his success had been great with the oscillating engine, he found it necessary to compress his engine into as small a space as possible, and to place it low down in the vessel, so as to be under the water line and practically below the line of shot penetration. He consequently adopted the "trunk" engine, for which a patent was taken out in 1845.

In October, 1845, he was commissioned to supply direct-acting engines on the horizontal trunk system, for the "Arrogant" and "Encounter," each of 360 nominal HP. The engines were so admirably executed, so compact, so finished in every respect, that fresh orders flowed in upon Mr. Penn continuously, and up to the day of his death, he had fitted 735 vessels with engines having an aggregate actual power of more than 500,000 horses. Among the first ships he supplied with trunk engines, were the "Agamemnon," the "Impérieuse," the "Royal George," the "St. Jean d'Acre," the "Cæsar," the "Colossus" (or the "Goloshes," as the seamen call it), the "Conqueror," and the "Orion." These ships were engined in 1853–4–6. Though the "Conqueror" for instance, was fitted for 800 HP., it actually indicated on trial 2,812 HP. These vessels were followed by others of larger size and greater steam power, especially after ironclads came into existence. The application of defensive armour to ships of war was not at first considered safe, but Napoleon III., when Emperor of the French, had the sagacity to see its importance. In 1855, four vessels were covered from stem to stern with iron armour-plates. It was the use of one of these ships that led to the successful assault of Kinburn at the mouth of the Dnieper; while our wooden ships at Sebastopol were unable to resist the attack of the enemy's shot and shells.

While the Crimean war was raging in 1854, the admirals found themselves at a great loss for want of gunboats for sounding the way for the larger ships in ascending rivers, and for other purposes of attack or defence. The Government at once ordered one hundred and twenty of them, with 60 HP. engines, to be ready at the beginning of next spring. It was at first thought difficult to accomplish so large an amount of shipbuilding in so short a time. But the result showed what an immense number of warships the workshops of England can turn out in the event of war. Mr. Penn solved the difficulty. He called to his assistance the best workshops of the country; he provided them with patterns, from which duplicate parts were executed and forwarded to Greenwich; and by the admirable resources of his own establishments at Greenwich

and at Deptford, he was able to supply ninety-seven gunboats for the spring of 1855. In all, one hundred and twenty-one engines were fitted by Mr. Penn for the British Government during the Crimean war. The lesson which it taught will not soon be forgotten either at home or abroad, though a great deal more can be done now.

Towards the end of 1858, the Admiralty were induced to take into consideration the construction of iron-clad ships of war. The subject was one of great difficulty. An enormous burden of armour had to be added to the weights hitherto carried; at the same time greater speed was demanded, and this involved an increased weight and power of engines, and a larger supply of fuel.

The "Warrior" was the first of these iron-clad ships. She was launched on the 31st of December, 1860. She is a splendid ship, constructed on beautiful lines, but as she was iron-cased in the strongest parts only 4½ inches thick, she is now comparatively helpless in consequence of the increased penetrative power of steel shot. The engines, constructed by Mr. Penn, were of 1,250 nominal HP., but might be worked to upwards of 5,000 indicated HP. The weight of the engines was 950 tons, and that of the whole armament from 9,000 to 10,000 tons. The five thousand pieces of which the engines were composed were fitted together with such precision, that when the steam was let into the cylinders, the immense machine began to breathe and move like a living creature, stretching its huge arms like a new-born giant, and then, after practising its strength and proving its soundness in body and limb, it started off with the power of over five thousand horses to try its strength in breasting the billows of the North Sea.

The "Black Prince" was the next of the ironclads. It was also engined by Mr. Penn, and proved equally satisfactory with the "Warrior." It would be unnecessary to mention all the numerous ironclads and other ships for which Mr. Penn provided the engines, but the following may be cited: the "Orlando," "Howe," "Bellerophon," "Inconstant," "Devastation," "Northampton," "Hercules," "Achilles," "Minotaur," "Neptune," and "Northumberland." The "Sultan" gave an indicated power of 8,629 horses, and the "Neptune" (formerly "Independencia") upwards of 8,800 indicated HP., about the highest hitherto realised by one pair of engines.

Another invention of Mr. Penn's remains to be mentioned. It may be remembered that at the beginning of screw-propulsion, a

difficulty was experienced in the heating and wearing of the screw gear. Hence there was a great prejudice against high-speed engines of every kind. Brass, cast iron, and soft metal were tried ; but no material could be found to stand the strain and wear. The bearings were rapidly worn away, there was an intolerable noise, and danger to the ship from fracture to the stern tube, besides the loosening of the stern framing, and the wear and tear of the screw shaft under water. The difficulty was so great that at one time screw-propulsion seemed in danger of abandonment, and a return to paddle ships was supposed to be necessary. At this juncture Mr. Penn instituted an exhaustive series of experiments with various kinds of metal and wood, and the result was the application of lignum-vitæ bearings to the screw shafts of steamers. He patented the invention in 1854, and, as usual, his patent was infringed by many shipbuilders. He proceeded against them by law, and in every case his rights were upheld. The first vessel fitted with the lignum-vitæ bearings was the "Malacca." It had previously given serious trouble with her outer screw-shaft bearings, wearing the metal away at the rate of 3½ ounces per hour. The wood bearings introduced by Mr. Penn proved a thorough success, and after 15,000 miles steaming were found to have become worn to the extent of only $\frac{1}{32}$ of an inch. By this means the practicability of screw-propulsion was thoroughly established.

Thus Mr. Penn's success was the result of a constant study of his profession. He devoted his whole life to his work. He was alike great as a mechanic, as an engineer, and as a man of business. He had a keen insight into men. He rapidly took the gauge of character. Hence his knowledge of the men best fitted to help him in his work. His partners, Mr. Hartree and Mr. Matthew, once his apprentices, were his devoted friends and helpers. The patent for the trunk engine was taken out in the names of the three partners. While never allowing the absolute control of the business to pass from him, Mr. Penn found in them such true friends that he was enabled to take at intervals considerable periods of rest, so necessary to one whose activity and powers of work were so large. Mr. Hartree and Mr. Matthew, now sometime deceased, were both Members of the Institution of Civil Engineers.

Superiority in every respect was his chief aim. "I cannot afford," he said, "to turn out second-rate work. I must have the best workmen and the best materials." The engines con-

structed by him were distinguished for their elegance and their symmetry. They were skilfully designed, and were so artistically finished that they might have graced a drawing-room. At the Paris Exhibition of 1867 he exhibited a pair of marine engines, which, though they were of no great size, left other competitors far behind. Their finish and their simplicity attracted the admiration of all competent observers. Mr. Penn was there at the time, and it was observed that his merit was only excelled by his modesty.

Mr. Penn was elected an Associate of the Institution of Civil Engineers in 1826, and was transferred to the class of Member in 1845. He served on the Council from 1853 to 1856. He was elected a Member of the Institution of Mechanical Engineers in 1848, and occupied the Chair as President in 1858–9. He was a second time elected to that position in 1867–8. He read several Papers before that Institution. In 1859 he was elected a Fellow of the Royal Society, and in 1869 he was elected an Honorary Member of the Society of Engineers.

Early in 1847 Mr. Penn married Ellen, daughter of the late Mr. William English, of Enfield, and leaves four sons and two daughters. In 1872 he took his two elder sons into partnership, and retired from the more active duties of the business. In 1875 he retired absolutely from the firm, his two sons becoming the heads of the establishment, which employs upwards of 2,000 men.

Mr. Penn was endowed by nature with rare social qualities, and was of a most hospitable disposition. For many years he assembled large numbers of guests at the Cedars, Lee. There might be seen men of the highest distinction in art, science, and literature—the best engineers, the best painters, the best philosophers. The summer-evening gatherings were looked forward to with pleasure; they were enjoyed with delight, and left many happy remembrances.

Towards the end of his life Mr. Penn became paralysed in his lower limbs, and later he became blind. Though he felt most keenly the gradual loss of his best sense, nothing could exceed his patience and his gentleness. He was most resigned and cheerful. His wife and family were always about him, and did all that they could to cheer and amuse him in his affliction.

When old friends called he amused them with his infinite fund of anecdote, for he had a wonderful memory. He was pleased to

speak of the early engineers, and of those who had helped him on in his successful journey through life.

Although to a certain extent bedridden, when the summer-time came, he was carried on board his beautiful yacht the "Pandora." He remained in the covered cabin, and visited the Loire, or the Seine, or the coast of France. In like manner he visited Belgium and Holland, sailing along the great canals. One of his last visits was to the coast of Italy. When the steam yacht stopped at a seaport town visitors flocked on board to see the ship. Mr. Penn was always glad to chat with them in their own language, whether it were French, German, or Italian.

He died on the 23rd of September, 1878, at the age of seventy-three; and thus passed away a great man, one of the most distinguished workers of this age and country.

Mr. WILLIAM WEST, the second son of a family of fifteen, was born in 1801 at Dolcoath, near Camborne. He was one of the many men born in that district who have raised themselves to prominent positions in the world by their industry and talents, and who have left their mark on their day and generation. Mr. West's father was connected with the famous old mine of Dolcoath, for which he managed the mine farm, and was also accustomed to buy the horses required by the adventurers. His son William received but a scanty education at a dame school. While still very young he was put to work on the mine, first at the surface, and then underground with his brother-in-law, Thomas Opie. His health failing, he stopped work for a time, but afterwards resumed it for a while, working on tribute with a young fellow of his own age, named John Rabling, who afterwards became manager of some important silver mines in Mexico. Mr. West and Mr. Rabling remained fast friends all their lives. Renewed ill-health at the age of seventeen compelled young West finally to abandon mine work, and it was not long before an opportunity arose for carrying out a long-cherished wish of becoming an engineer. This was at the time when great improvements were being made in the steam engine, by a notable band of Cornish engineers, of whom Trevithick, Woolf, Andrew Vivian, and Hornblower were among the chief. Trevithick was engaged on his Cornish boilers, his high-pressure "puffer" engines, and his locomotive. Mr. West always

recalled with pride the fact that he once held the candle to Trevithick while he was engaged in the construction of the locomotives. Andrew Vivian and Trevithick had been occupied on their road steam carriage. Woolf was producing his two-cylinder compound engine, which, after lying many years in abeyance, was at length resuscitated, to produce a revolution in marine engineering. Watching the work of such men as these, West had his desire to become an engineer still further stimulated. One day, a brother-in-law, William Mathews, working engineer on Dolcoath, was turning a piston-rod for a winding engine with the old-fashioned hand tool. Mr. West was asked to try and rough-turn the rod while Mathews was called away to attend to a breakage in one of the engines. When Mathews returned, he found, to his surprise, that the work had been executed in a very creditable manner. This led to young West's obtaining employment in the fitting shop, where his indomitable industry and quickness of perception soon brought him into notice. Mr. West's first independent employment, apart from Dolcoath, was his engagement as a working engineer by Captain Joseph Vivian in erecting a pumping engine at South Roskear; and he was soon afterwards engaged in a similar capacity in erecting engines on several neighbouring mines. These works led to his paying frequent visits to Hayle Foundry, where he attracted the attention of the late Mr. Henry Harvey, founder of the well-known firm of Harvey and Co. One of those periodical depressions to which mining has always been liable throwing Mr. West out of work, Mr. Harvey introduced him to Messrs. Bolitho of Penzance, who engaged him to erect an engine to work a flour mill. So successfully was this carried out that Mr. Harvey ever afterwards took a deep interest in Mr. West's career, and furthered his interests in every way he could. Mr. West's next engagement was on the Great Wheal Towan mine, St. Agnes, reworked by Captain Nicholas Vivian, with Captain S. Grose as chief engineer. At this mine were erected a couple of 80-inch cylinder pumping engines, the most powerful at that time in Cornwall. During one of the intervals between his chief's periodical visits of inspection, and with the consent of Captain Vivian, Mr. West had the boilers of one of the pumping engines covered with sawdust, to prevent radiation. Up to this time, boilers and steam pipes had always been left uncovered; and this method of protection resulted in such a reduction in the consumption of coals, that Captain Grose, at his next visit, had the cylinder and pipes enclosed with the same material. The result was

such an increase in the duty of the engine, that the reports were received with a great deal of suspicion by the mine agents and engineers, until a public trial completely vindicated the reported duty. Mr. West remained at Wheal Towan two or three years, and during that time largely extended his store of information by his acquaintance with a well-educated friend named Davis. In 1831, being strongly recommended by Captain Vivian, the late Mr. J. T. Treffry appointed Mr. West engineer to the famous Fowey Consols and Lanescot mines, then approaching the height of their productiveness. Here he had the entire control of the engineering department, and his work speedily attracted the attention of the whole mining community of the county. It was in 1833–34 that he erected at Fowey Consols an 80-inch pumping engine, which embodied all the latest improvements, and which in July 1834 had a reported duty of 90 millions, and in the following September one of 97·8 millions. Not unnaturally, the accuracy of these astounding figures was questioned. A public trial then took place, which lasted twenty-four hours, and which far more than substantiated the duty reported. As the result of the trial, the committee of engineers who had conducted the investigation stated that the duty done in the twenty-four hours was 125 millions of pounds raised 1 foot high, by the consumption of 94 lbs. of coal. The success of this engine soon brought Mr. West an abundance of work from all parts of Cornwall and Devon, and it was not long before his engagements extended to the most distant parts of the kingdom; while in later years he supplied engines and other mining machinery to various parts of the continent of Europe, to North and South America, Africa, Asia, Australia, New Zealand, and, in fact, to almost every mining district in the world. About this period Mr. West became partner with the late Mr. William Petherick, but this association lasted only a short time, and Mr. West, working single-handed with a constant application and determination which were characteristic of him, soon had his hands full of engagements as a mining engineer. In 1835 the directors of Holmbush mine presented him with one of the many testimonials he received, in record of their appreciation of the skill he had shown in erecting their machinery. About the same time he erected, at South Hue mine, the first of the steam capstans, which are now to be found on almost every mine, and which have proved so economical to the adventurers, and have been such a boon to the working miners, in reducing one of the most disagreeable parts of their work, "capstanning." In 1838 the

late Mr. T. Wicksteed, M. Inst. C.E., visited Cornwall, on behalf of the East London Waterworks, and inspected a number of pumping engines.[1] Struck with the excellence of that at Fowey Consols, he purchased a similar one, which Mr. West had erected at the East Cornwall mines. Mr. West contracted to remove and re-erect it at the Company's works, and Messrs. Harvey, of Hayle, engaged to make the necessary pump work. The diameter of the plunger rod of the pump was 42 inches, and it had a working load of about 32 tons. It was fitted with the common butterfly valves, but the great dimensions of the pump and the enormous load rendered it impossible to work under such conditions. The vibration and shock were tremendous, and it was speedily evident that a radical change was needed somewhere. Mr. West's inventive genius soon overcame the difficulty by devising the double-beat water valve, which was found to work so effectively that it was patented by Mr. West and Mr. N. Harvey, and proved very remunerative to the patentees. The success of the operations at the East London Waterworks also led to Mr. West's being engaged to fit up pumping apparatus in connection with many other large waterworks in the metropolis and other parts of the country. The directors of the East London Company gave him a handsome testimonial. The steady increase of Mr. West's business engagements, and his unwearied activity led, in 1848, to the establishment by him of the foundry and engine-works at St. Blazey, now carried on by his sons Messrs. W. and C. West. He was never idle, and, although for many years connected with numbers of the largest mines in the county, he found time to undertake several other important works. He contracted for building the engine houses for the atmospheric system on the South Devon line, and when this proved a failure, he agreed to receive as payment the materials which the abandonment of the atmospheric system had rendered waste. It was by Mr. West that the Newquay and Cornwall Junction Railway was constructed; and he was the contractor also for the Bodmin and Camborne Waterworks. Nor did his own special calling and such kindred matters by any means exhaust his energies. He was one of the founders, in the year 1864, of two of the most flourishing banks in Cornwall,

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[1] The Transactions of the Inst. C.E., vol. i., pp. 117-130, and vol. ii., pp. 61-65, contain Papers by Mr. Wicksteed "On the Effective Power of the High Pressure Expansive Condensing Steam Engines in use in some of the Cornish Mines."

viz., Messrs. Willyams, Treffry, West & Co. at St. Austell and Fowey, and Messrs. Clymo, Treffry, Hawke, West, Polkinghorne & Co. at Liskeard, Bodmin, &c. He held a large interest in various mines, clay works, and quarries; and at the time of his decease was the principal proprietor of Phœnix and West Phœnix United tin and copper mine, and of the Par granite quarries. Phœnix mine, indeed, had been saved from extinction purely by his courage and foresight; and one of the testimonials which Mr. West most valued was that presented to him by the working miners there, in grateful recognition of his labours in preserving what is now one of the most valuable mining properties in the county. The adventurers also most generously recognised the value of his work in this direction. The shareholders in Par Consols Tin and Copper Mine also presented him with a splendid silver tea and coffee service.

Among Mr. West's inventions was one, patented in conjunction with Mr. Darlington, for transferring power in mines by means of hydraulic agency. While Mr. West was engaged at Fowey Consols, the mine was visited by the late Bishop of Exeter, who was at once struck with the shrewdness and capacity of the engineer, to whom his lordship had been introduced by Mr. Treffry. Dr. Philpotts would have no other companion than Mr. West during his inspection; and this led to Mr. West's appointment as mineral agent or toller to the see. This appointment Mr. West retained, assisted by his son-in-law, Mr. William Polkinghorne, for many years, then acting for the Ecclesiastical Commissioners as agent and receiver jointly with Mr. Polkinghorne until the year 1879. The last, though not the least, of the important undertakings carried out by Mr. West, was the taking down of an 80-inch engine at Wheal Pembroke, repairing and refixing it, with additional machinery, at the Great Holway lead mine in Flintshire. This engine was first erected at Par Consols, and thence removed to New Pembroke. It is now the most powerful engine in the district to which it has been transferred.

Mr. West died at his residence, Tredenham House, St. Blazey, after a short illness from heart disease, on the 16th of June, 1879, at the good old age of seventy-eight years. Though delicate in youth, for nearly half a century he had hardly known what illness meant, and his mind remained bright and clear to the last. Mr. West was twice married, and had three sons and two daughters by his first wife. These children with his second wife survive him. He acquired considerable wealth, which was

partially invested in landed estates, and which, apart from a few legacies, he has divided equally between his children, directing that the whole may be kept intact for twenty years from his decease.

Mr. West was elected a Member of the Institution of Civil Engineers on the 12th of February, 1839. He remained a thorough Cornishman throughout his life, proud of his native county and proud of his origin, and of his having made his own way in the world. He was straightforward in all his doings, plain and downright in speech, but with a kindly heart—always ready to do a good turn to those who needed it. He interested himself in the various county institutions and societies, and had a vein of native humour which made his company most enjoyable. He possessed a fund of quaint stories and reminiscences upon which he was never weary of drawing, and which were all the more valuable because in him passed away the last link between Cornwall of the days of Watt and Trevithick, and Cornwall of the present—the last of a school of mining engineers that made the old county famous.

MR. FRANCIS DAWSON was for some time a student in the Applied Sciences Department, King's College, London. In 1852 he entered the office of Mr. W. H. Barlow, President Inst. C.E., as a pupil, and afterwards went to the Crimea in the Army Works Corps, where he was engaged on the telegraph staff. On his returning he continued his articles with Mr. Barlow, and for a short while acted as the assistant of Mr. T. F. Chappé, M. Inst. C.E., on the Gloucester and Stonehouse railway. In the autumn of 1858 he obtained the appointment of "Assistant Engineer," Jamaica; in 1861 he was promoted to be "County Engineer," and in 1868 to be "Deputy Director of Roads." In these several capacities he was engaged in the construction of new roads, improving the communications throughout the island, and in the erection of government buildings. In several cases he exercised much engineering skill in spanning rivers. One of the works he designed and successfully carried out was the Victoria Market, Kingston. He organised and introduced a better means of extinguishing fires, which are frequent and destructive in Jamaica, and formed a fire brigade for that purpose. He was remarkable for an originality of character and inventive talent which attracted

those with whom he came in contact. He entered into the work he had in hand with a singular thoroughness of character, and exhibited a command of resources and indefatigable industry and interest in his duties. He came to England at the end of 1878 for change and rest; but on his return to Jamaica, early in 1879, he died suddenly. Mr. Dawson was elected an Associate of the Institution on the 7th of March, 1871.

MR. JOHN HANVEY, a native of Dublin, was an Irishman in the best sense of the word, possessed of shrewdness of character combined with urbanity of temperament and disposition. From his earliest years he showed an aptitude for scientific and mechanical pursuits, and became a proficient in mathematics at one of the best private schools in Dublin. When almost a boy he obtained employment on railways in Ireland under Mr. W. McCormick, and often encountered strange adventures in the pursuit of his calling as Manager of Works. He afterwards served on the Liverpool and Bury railway, and as Manager of Works to Messrs. Williams, Ackroyd and Co. He spent some time at Penrith in Cumberland, and for several years was engaged on the Birkenhead Dock Extension Works. From thence he went to Gloucester as the City Surveyor, where he formed a reservoir embankment outside the city boundary; and in 1861 he was elected, out of sixty candidates, Borough Surveyor of Dover. Here his labours were many and varied; the construction of an additional reservoir at the waterworks, the improvement of the borough prison, the original East Cliff revetment, the extension of the main drainage, and the laying out of the Maison Dieu estate came under his direction. He designed and carried out a scheme for separating the upper and lower services of supply from the waterworks, and inaugurated a system of water inspection that effected considerable economy. Later he designed and executed a comprehensive scheme for separating the surface water from the sewers, and shortly before his death completed the East Cliff sea-defences. Mr. Hanvey was one of the earliest advocates of the Rifle Volunteer movement, and for many years was connected with the Dover corps, from which he ultimately retired with the rank of captain. Mr. Hanvey was elected an Associate of the Institution of Civil Engineers on the 3rd of December, 1850, and during the discussion of a Paper on "The Brighton Intercepting and Outfall

Sewers," by Mr. Gamble in December 1875, gave some interesting particulars relating to the water supply and sewerage of Dover.[1] He died suddenly of apoplexy on the 5th of November, 1879, aged fifty-five years.

Mr. RICHARD SECKER BROUGH, youngest son of Dr. Thompson Brough, M.D., was born at Kiltegan, in the county of Wicklow, on the 17th of October, 1846. His early education was pursued at a private school in Jersey, kept by a Mr. Thompson; and later at the Victoria College, in those days ably ruled by Dr. Henderson, whose prim yet kindly manner and impartial treatment rendered him a great favourite with the boys. In a society like that of Jersey, where many retired military officers had settled, and where the troops garrisoning the island were held in high esteem, most boys naturally inclined to the army as the profession of their choice; and as two elder brothers had already joined the service, young Brough was strongly inclined to follow their example. However, it was decided that he should study for the Indian Civil Service, and with this object in view he was sent to Avranches, in France, where more individual attention could be bestowed upon him than was possible in a large school. Here he quickly acquired a perfect knowledge of the French language, learned Italian and German, natural and physical sciences, and showed a permanently increasing interest in mathematics. It was then that his talent for physical research began to be perceived. He returned to London to continue his preparations; but, notwithstanding his natural ability, there was not time to accumulate that large amount of positive knowledge which is required to pass successfully through the ordeal of an Indian Civil Service Examination: he failed, and being over age, another profession had to be selected.

About this time Sir Stafford Northcote, Bart., M.P., had introduced the present system of examination for the Indian Telegraph Service. Mr. Brough got nominated for that service, and, after another year's study at University College, London, and under Mr. W. H. Preece, M. Inst. C.E., he passed first in the examination. He was appointed, by the Secretary of State in Council for India, a fourth grade Assistant Superintendent, with effect from the

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xliii., p. 221.

30th of October, 1869. On arriving in Calcutta, on the 8th of January, 1870, he was posted to the Telegraph Stores and Workshops for instruction; but his skill was so marked that he was promoted to Assistant Superintendent of Stores on the 5th of May in the same year. In the November following he was transferred to Madras, to take charge of that important telegraph office. In March 1871 he was recalled to Calcutta, to become an assistant to the Superintendent Electrician, which important position he retained up to the time of his death. In the electrician's office, where physical experiments of a varied nature are daily executed, he had every opportunity to develop his special talents, which he did with marked success. During the absence from India of Mr. Schwendler, M. Inst. C.E., the Superintendent Electrician, he was invariably deputed by the Director General to officiate for that officer, on account of the great ability he had shown in all the technical branches connected with the telegraph administration. He was thus mainly occupied in special duties; but he constructed the line of telegraphs from Kureli to Saugor, 70 miles; and his latest practical work was undertaken for the purpose of testing and repairing the faulty Paumben cables in connection with the Ceylon cable, which he carried out most successfully.

Mr. Brough was one of the most active members of the Asiatic Society of Bengal, and since 1871 he had been a member of the Physical Science Committee of that society. To the Proceedings of that body he contributed the following Papers: in 1877, "On a case of lightning, with an evolution of the potential and quantity of the discharge in absolute measure;" "On the diameter of the wire to be employed in winding an electro-magnet in order to produce the maximum magnetic effect;" "A theoretical deduction of the best resistance of a telegraph receiving instrument;" "Note on Professor Graham Bell's telephone;" and in 1878, "A few magnetic elements for Northern India;" "On the proper relative sectional areas for copper and iron lightning rods." The night before his death, which occurred suddenly, from cholera at Calcutta, on the 3rd of April, 1879, he attended, in apparently full health, a meeting of the Asiatic Society, where he assisted in showing experiments in connection with a Paper on "A new standard of light,"[3] read by Mr. Schwendler.

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. liv., p. 386.
[2] *Ibid.*, vol. lxvii., p. 421.
[3] *Ibid.*, *post*, p. 428.

He also published a small book containing useful formulæ for practical telegraphy; afterwards incorporated, under the head of "Telegraph Construction," in the 19th edition of Molesworth's "Pocket Book of Engineering Formulæ;" to which was added, "Electrical Formulæ, &c.," by Dr. Higgs and Mr. Brough. He further brought out, by order of the Director General of Telegraphs in India, a second edition, revised and amplified, of "Instructions for Testing Lines, Batteries, and Instruments," by Mr. Schwendler; and in a Supplement to vol. i. he gave a "Table of Correction Coefficients."

He was elected a member of the Society of Telegraph Engineers in May 1872, a member of the Physical Society of London in June 1875, and an Associate of the Institution of Civil Engineers in February 1878. He possessed all the qualities to become in time an eminent physicist and telegraph engineer; but great as were his mental gifts and accumulated knowledge, both were surpassed by his kind and generous disposition, especially shown towards those who had the fortune to serve under him.

MR. EDWARD TAYLOR SIMPSON was born in Manchester on the 8th of October, 1843. He was apprenticed to Messrs. John Samuels & Co., warehousemen; but the Manchester trade not being congenial to his taste, inheriting as he did a bent for engineering from his father and grandfather, he accompanied his eldest brother, Mr. James C. Simpson, M. Inst. C.E., to Buenos Ayres. There, from November 1863 to September 1864, he was an assistant to Mr. John Coghlan, M. Inst. C.E., and Mr. J. C. Simpson, on the surveys and construction of the Buenos Ayres and Ensenada Port railway; while from September 1864 to March 1865 he was employed on the surveys for the railway from Port Ruiz to Gualequay, in the province of Entre Rios, and also on the surveys for the extension of the Northern railway. From 1865 to 1869 he was sub-manager of the Ensenada railway; from 1869 to 1870 he was engaged by Mr. Coghlan on the surveys of the Buenos Ayres city improvements; and he succeeded his brother, Mr. Harry Simpson, in the latter year, on the nomination of Mr. Wheelwright, in the post of General Manager of the Ensenada railway, which appointment he retained until the line was taken over by the present company at the close of 1877. Lastly, he took charge of the construction of one of the sections of the Buenos Ayres city

improvements, which Mr. J. C. Simpson had undertaken as contractor.

He had a good general knowledge of works; understood the carrying out of plans, and the economical direction of men; was active, obliging, and intelligent, and inspired confidence by never being absent from duty for a day during the two years that yellow fever and cholera were prevalent in Buenos Ayres. Out of business he was a great favourite, on account of his kind, genial temperament, and his ability as a musician and as an athlete. He died from sunstroke, received while playing cricket, on the 20th of December 1878. He was elected an Associate of the Institution in March 1876.

SECT. III.

ABSTRACTS OF PAPERS IN FOREIGN TRANSACTIONS AND PERIODICALS.

Remarks on Geodesy. By Prof. A. NAGEL.

(Civilingenieur, vol. xxiv., cols. 621–604.)

The Author first investigates fully the four methods generally used in projecting any given point vertically upon the ground surface, as in the measurement of base-lines. The plummet, the plumbing-cylinder, the theodolite, and rods whose contact is microscopically observed, are here discussed, the accuracy attained by each following in the order of their enumeration above.

He then details his own experience in the Saxony triangulation, where the stations consisted of granite or sandstone pillars, varying from 6½ to 23 feet in height, sunk 6½ feet into the ground. A point answering to the trigonometrical point is found by the plummet upon the scaffolding erected over the foundation, and "plumbed" down upon the pillar after it is built. The station itself is marked by a cross on a brass cylinder sunk into the foundation, the pillar-top on which the theodolite is afterwards to be set up being similarly provided; but this second cylinder was protected by a stone or cast-iron cover. In addition to this, four square stones are sunk 1½ foot under the ground at the sides of the pillar, each also with a cylinder and a cross, so that the junction of two opposite marks shall intersect in the vertical plane of the trigonometrical point.

Two courses were followed for accurately fixing in position the cylinder on the pillar-top: 1st, With pillars up to 8 feet high; and when the four side-marks are close to them, a straight-edge was placed upon the pillar, at the ends of which hung two plummets; these, playing over two opposite side-marks in succession, gave by the intersection of the lines joining them upon the pillar the required station point. 2nd, With higher pillars the theodolite was used, being brought in turn either into the vertical plane passing through each pair of side-marks, or into planes parallel to these, and as near the pillar as possible. In the latter case the station point was afterwards found upon the pillar by measurement. But as neither of these methods is free from objection, while in the first method the pole at the opposite side-mark may not, after every precaution, be strictly vertical, the Author devised the following apparatus: a short cylinder of 1-inch diameter, mounted on a tripod fitted with foot-screws, is bored perfectly true to receive a

steel cylinder $9\frac{1}{2}$ inches long, which fits it exactly, and terminates at each end in a fine point exactly in its axis. A bubble-tube is fixed to an arm on one side of this cylinder, for the purpose of placing it vertical, and on the opposite side there is a counter-weight. Whenever the truly vertical cylinder axis is brought over any given spot, a mark is made on the wooden (or leaden) plate underneath it, by gently pressing down the cylinder.

In plumbing up or down from small elevations it was seldom possible to bring the end of the measuring rod over the side-mark, especially when a parallel vertical plane had to be traced. The Author then used an angle-iron mounted on a wooden plate having three foot-screws, on which a bubble-tube was placed to test the verticality of the upright limb. A finely-pointed ruler is made to slide along it, and thus is brought exactly over any required point, x; the ruler, being removed, a measuring rod is laid in its place against the vertical side, and the measurement from x can proceed. The mean error in projecting a base point vertically was found to be only $\pm$ 0·41 millimètre, and this even was partly due to settlement in the pillars.

Two instances are next given of deep plumbing carried out by the Author. In the first case a point had to be transferred from the lower to the upper gallery of the Pleissenburg, at Leipsic, a height of $53\frac{1}{4}$ feet, and as neither the plummet nor Stampfer's level could be used for the purpose, a special instrument was designed, which answered admirably. Three views and several detailed sketches are given in illustration. It is a transit instrument on the tribrach principle; the body is of cast iron with an opening in the base of the same size as the object glass, to allow of a vertical downward observation; it is attached to the tripod by a collar, and is provided with a clamp and tangent screw. A striding-level, reading to 6 seconds of arc for each scale division, and protected by a cloth cover from sudden changes of temperature, adjusts the horizontal axis of the instrument when used as a transit; while a telescope-level, reading to 7 seconds of arc for each division of $\frac{1}{10}$ inch, adjusts the vertical axis for plumbing. The latter is screwed on, when required, to one end of the telescope pivot, which is thickened for this purpose and acts as a counterweight, the opposite end being provided with a clamp and tangent screw. The telescope has a magnifying power of 19, and a focal length of $9\frac{3}{4}$ inches.

An important addition is the nadir attachment, which screws into the opening in the base of the instrument. It consists of a hollow cylinder, fitted with a smaller inner and concentric cylinder, carrying a steel cylindrical pin with a fine point, for showing the accurate centering of the instrument over any spot. The pin is capable of slight lateral motion by a spring, as the telescope axis must lie exactly in that of the pin, when used vertically.

As a further help, the Author also constructed a slide-apparatus consisting of a white plate with a black cross on it, which slides in

two directions at right angles to each other in guide rests, the amount of each movement being given by a Vernier reading to $\frac{1}{10}$ millimètre on two millimètre scales. The apparatus is mounted on a thick iron plate lacquered white, on the edge of which are four black strokes for showing the directions of the movements of the plate, numbered respectively 1, 2, 3, 4. It is fastened over the position of the required point by screws at the four corners, after which, the telescope being set up over it and adjusted, the accurate position of the cross is found by the cross-hairs, and the movement given to each slide is read off on the proper scale. Two readings are taken in each direction.

The vertical position of this telescope was tested with a quicksilver horizon instead of with a bubble-tube, by reflecting the cross-hairs, and making the two images coincide, after which the horizon is removed, and the point plumbed down. For proper illumination of the cross-hairs a piece of plane and parallel glass is screwed on in front of the eye piece at the required inclination. To avoid eccentricity in the telescope, a second observation should be taken with the artificial horizon, the instrument being turned through 180°; a fresh point is then plumbed down, the mean between the two being the true point.

Details of the work done by this apparatus, on the 9th July, and 4th August, 1878, at the Pleissenburg, are given. The mean error in a double observation, in either direction, on the first day, amounted to $\pm$ 0·123 millimètre; on the second, to $\pm$ 0·136 millimètre;—a result hardly to be expected. This plumbing was repeated with the artificial horizon, but the results were not so good, while the method is more laborious, more inconvenient, and less rapid than with the bubble-tube: the mean error then amounted to $\pm$ 0·261 millimètre.

To test this apparatus at greater depths, the Author used it in Günther's shaft near Bocka, which was 433 feet deep. The slide apparatus was illuminated by four bull's-eye lanterns, but the light being imperfect, the experiment was successfully repeated on the 6th of October, with an improved petroleum lamp (details and drawings of which are given), the centre of a black circle of $\frac{1}{2}$-inch diameter upon an ivory plate being the point observed. The accuracy of the observations on the second day was twice as good as on the first, and might have been still better, had more observations been taken, and a more sensitive bubble-tube been used.

E. H. C.

Schneider's Telemeter.

(Repertorium für Experimental Physik, vol. xv., p. 171.)

The idea of constructing a telemeter was first suggested to the Author in 1874, in connection with plane table surveys, but given up when such good results were obtained with Reichenbach's and

Stampfer's telemeters. He then turned his attention to devising an instrument by which distances might be found directly, and abandoning the notion of a pocket instrument, designed one especially for naval warfare.

A good telemeter must satisfy the following requirements:— It should find the distance of a visible object directly; it must give this distance even though that object is in motion, and even if its size is unknown; the motion of the surface on which it stands must not affect the operation; it must be easily handled, and give distances from 3,000 mètres to 4,000 mètres ($1\frac{3}{4}$ mile to $2\frac{1}{2}$ miles) with accuracy.

Now, though several telemeters have been invented in Germany, France, and America, all of them fail to satisfy the whole of the above requirements. Schaub's—like the sextant—would prove the best, were it not imperative in both instruments to know the dimensions of the object sighted, in order to calculate its distance.

Starting, therefore, with the condition that a base is indispensable, the Author calculated values of α (the micrometric angle subtended by the base) for distances up to 4,000 mètres, when, with a base of

	Mètres.		Min.	Sec.
4 mètres for a distance of . .	4,000	$\alpha =$	3	26
6 " " . .	4,000	$\alpha =$	5	9
8 " " . .	4,000	$\alpha =$	6	52, &c.

Each decrease of 20 mètres gave, for each of the above bases, angle differences of 1 second, $1\frac{1}{2}$ second, 2 seconds, down to 3,000 mètres. For lesser distances the values evidently increase more rapidly.

In any triangle A B C, let A B = a, the base of the telemeter = 6 mètres long, b = B C, the distance sought = 4,005 mètres long, α = the angle measured, C D = $\Delta\, b$, the difference by which B C may increase, δ = the angle by which α becomes smaller when B C is increased; then, since $b = a \cot \alpha$, whence α = 5 min. 9 sec., if $\Delta\, b$ be taken as 50 mètres, δ in seconds = 3·8, a value which is easily and accurately measured with Stampfer's screw.

It might seem at first sight that the base length (a) must be strictly accurate, and must not be affected by changes of temperature; but it is shown that even if the 6-mètre base varied a whole centimètre (0·4 inch), an error of only $\pm$ 6·7 mètres (22 feet) would result in a distance of 4,000 mètres, an error quite inappreciable, especially since the brass of which the instrument is made would only expand or contract 1 millimètre (·039 inch) by a rise or fall of 17° centigrade in temperature.

The instrument consists of a base tube made up of x lengths, at one end of which is a rectangular prism, which reflects the rays coming from the object at an angle of 90° into a refracting telescope inside the base tube, while at the other end is a movable telescope, about $15\frac{1}{2}$ inches long, for direct vision of the same object, motion to which is given by a micrometer screw: by this means the angle between the direct ray and that entering the prism can be read off upon this screw.

First End-piece.—This terminates in a square case, in which is fixed a prism, and above which is a cover for keeping off side lights. The case turns in the joint of the first tube-length in two directions; to this length are fixed successively x tube-lengths, to make the instrument, at will, either 4, 6, 8, 10, or 12 mètres long. The last length fits into the other end-piece with three screws, working in elliptical slits, motion about its axis being given to the whole instrument by two antagonistic screws working against a boss at the top of this length. Two micrometer screws for adjusting the prism work along the whole length of the instrument, and are carried underneath it in supports. It is highly important that the prism should stand perpendicular to the line of sight passing through it into the base telescope.

Second End-piece.—This also terminates in a square case. At the end next the last length is the object glass, capable of being focussed by a mill-headed screw; this concentrates the rays from the object, reflected through the first prism, to the eye-piece (which is at the bottom edge of the square case) through a second prism, P_2, placed just above it in the case: above the latter is a covering tube, which extends to the second and movable telescope. This second telescope has the axis of motion in the plane of the diaphragm, which is in front of the eye-piece common to both the telescopes. A bent arm attached to the square case carries the micrometer screw, which is further supported in the ring of the movable telescope. The object-glass of this telescope can be focussed similarly to that of the first one, both of them being drawn in or pushed out until the images of the same object are clearly visible in the eye-piece common to both. Two arms, fixed at opposite sides of the second telescope, and hinged to two pieces of metal projecting beyond the bottom of the square case, allow this telescope the requisite motion in the plane of the diaphragm.

Two sources of error have to be guarded against: 1st, the bending of the base tube, and the consequent distortion of the prism; 2nd, the incorrect position of the support for the micrometer screw, which would cause the reading upon the screw corresponding to a given distance to be inaccurate. To remove these, the following contrivance was introduced:

1st. To the diaphragm, which also carried the cross hairs, was fixed a small tin cross, painted black on the side next the eye, and dull red on that next prism P_2 and object glass of base telescope. A lens is fitted in front of prism P_2, and a mirror of the same size as this lens to base prism P_1. By this means the red cross will be reflected alongside the black one if prism P_1 is not in its proper position, when the necessary correction must be made by the two long micrometer screws carried underneath the instrument.

2nd. To test if the fixed position of the micrometer screw, by which the line of sight of the movable telescope is perpendicular to the base, has changed, or, if changed, to fix the amount of deviation, a lens is used in the same way as that already described for the first telescope, except that in this case the mirror is put

on a plate of plane and parallel glass inserted behind the object-glass of the movable telescope, which reflects the rays from the diaphragm into the image plane in front of the eye-piece.

It is evident that the whole image of any object can be obtained in two ways: first, the image halves may be placed side by side; or, second, one above the other. Greater accuracy is, however, ensured by the first method, as a slight lengthening or shortening of the object may else possibly occur. The principle of this telemeter is to have a constant right angle, at whose apex is a prism, the hypotenuse of the triangle formed by the object, the prism, and the diaphragm being the optical axis of the movable telescope. The distance is found on inspection from tables.

The probable objections to this construction are next combated in detail, and a second one proposed for the adjustment of the prism P_1 and for that of the rest of the movable telescope, in case it might be further urged that the production of a second image in the plane of the diaphragm would work badly, and that vicious rays would enter the telescopes through the arrangement proposed. In this construction a separate tube is provided in both the base tube and the movable telescope, for the purposes of adjustment only: a second eye-piece is of course necessary in consequence. Two plates fully illustrate the descriptions, for which particulars must be sought in the original memoir.

The method of adjusting the instrument is detailed, and a table is given of distances computed for certain values of a with a base length of 6 mètres, from which it is evident that long distances, up to even 10,000 mètres ($6\frac{1}{4}$ miles), may be found with tolerable accuracy. It is highly important that the sights of the two telescopes intersect in the object, in order to obtain a correctly, because on it depends the accuracy of the required distance.[1] For shorter distances than 4,000 mètres, a telescopic base tube of $1\frac{1}{2}$ mètres (5 feet), made up of five lengths, might be permissible, in which case a portable instrument would result.

The Author concludes by asserting that a base length of 4 mètres ($13\frac{1}{8}$ feet) might easily be used on all war ships of the present day, and even in full-rigged ships if placed in front of the foremast. The instrument can also be used in a horizontal position if mounted on a suitable stand; but, if its base were placed at right angles to the sea line of a turret gun, the distance could be found at the same time as the gun was laid. The use of this telemeter along a coast offers no difficulty, as at night the image halves of any light could be made to coincide as well as those of any other object.

E. H. C.

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[1] Were an observation error of $\pm$ 5 seconds made in a, when the object was 4,005 mètres distant, a displacement of the image halves to the extent of 4 inches would result, an amount which ought not to be possible.

On the Constitution of Portland Cement.

By Dr. L. Erdmenger.

(Thonindustriezeitung, vol. iii., p. 4 *et seq.*)

Some writers have regarded Portland cement as a mineral compound, in which the different substances are arranged according to stochiometrical laws. The Author is of opinion that cement is not, in itself, a body of definite composition, but a varying mixture of silicates which have been fluxed by means of lime. The proportion of lime may vary considerably without altering the appearance of the product; but to obtain hydraulic properties the limits are more narrow. The first stage in the hardening of cement is the partial decomposition of the vitrified mass by water. The new compounds thus formed determine the strength of the cement. Each grain of cement when brought into contact with water becomes converted into insoluble, gelatinous substances, which are the true cementing agents. The more intimately the raw materials are mixed before burning, and the more carefully they are burned, the more of these gelatinous substances will the cement yield. Portland cement may be regarded as a water-glass, in which the alkali is replaced by lime; the comparative insolubility of the latter enables the cement to resist the action of water. The gradual hardening which succeeds the initial "set" of cement appears to be due to the drying of the superfluous water. The gelatinous substances, deprived of this excess of water, solidify, and increase the strength of the mass. No fixed relation has been detected between the chemical composition of cement and the amount of water required, either for the initial set or the subsequent hardening. When cement is mixed with a minimum of water it is but slightly decomposed, and hardening takes place under the most favourable conditions. If, on the contrary, an excess of water be used, the proportion of decomposed cement becomes too great, and the strength is diminished. The real cementitious agent in Portland cement is silica, the presence of the lime being necessary to render the silica soluble. Theoretically, a perfect cement would be pure silica in its gelatinous form.

W. F. R.

Notes on Cement Testing.

(Dingler's Polytechnisches Journal, vol. ccxxxiii., p. 320.)

Dr. Böhme has published the results of the official tests of Portland cement made at the Royal Industrial Academy, Berlin. The breaking section of the briquettes used for testing the tensile strength was 5 square centimètres (0·775 square inch). The dimensions of the samples crushed were 10 × 10 × 6 centimètres,

the area subjected to pressure being 100 square centimètres (15·5 square inches). Each figure is the average of five experiments. In the following table the results are given in lbs. per square inch.[1]

No. of Test.	Neat Cement.							
	Days of Immersion in Water.				Days of Exposure to Air.			
	7.	30.	60.	90.	7.	30.	60.	90.
								Tensile
1	498	740	569	683	427	569	512	540
2	469	370	654	469	341	484	740	412
3	427	526	668	555	356	612	697	683
4	199	555	469	754	370	697	896	[redacted]
5	327	398	484	612	256	484	455	683
6	356	612	555	484	412	626	583	626
7	370	697	683	697	370	626	683	740
8	242	469	398	668	199	512	398	555
9	242	313	327	356	199	313	398	384
10	185	242	327	284	[redacted]	327	412	427
11	185	270	313	370	213	441	384	427
12	412	555	612	711	384	555	597	683
13	128	185	284	327	199	284	370	384
14	370	512	597	626	384	526	654	683
15	412	540	540	796	526	626	839	910
16	569	768	839	989	612	697	768	853
17	740	811	939	1,024	711	782	839	910
								Crushing
1	3,755	5,134	5,305	5,604	4,210	5,092	5,177	5,533
2	3,698	4,039	5,348	5,547	4,011	3,982	5,078	5,419
3	2,233	2,942	3,868	4,765	2,603	3,413	3,698	4,907
4	2,802	2,985	5,305	5,447	2,745	3,328	3,584	3,883
5	1,991	2,532	3,982	4,324	1,906	2,702	2,745	2,901
6	3,271	3,527	4,281	4,338	3,214	3,613	4,807	4,566
7	2,930	3,413	4,082	4,309	3,143	3,371	4,110	4,594
8	2,176	3,115	3,186	3,470	2,361	2,987	3,115	3,584
9	1,721	2,503	2,759	3,214	1,749	2,546	4,253	3,271
10	1,109	1,357	1,607	1,621	1,166	1,522	1,778	1,863
11	1,977	2,190	2,631	3,172	2,119	3,072	3,357	3,584
12	3,911	5,163	5,703	6,215	3,982	5,277	5,931	6,486
13	1,024	1,636	2,205	2,603	1,351	1,963	2,617	3,214
14	3,314	4,551	5,262	5,476	3,342	4,765	5,220	5,447
15	4,054	4,750	5,518	5,774	4,423	5,106	5,703	6,201
16	5,106	5,874	6,770	7,282	5,376	6,187	6,884	7,410
17	5,334	5,860	6,614	7,126	5,191	5,831	6,542	6,969

[1] Some of the results appearing low, Dr. Böhme was communicated with, and explains that Nos. 1–14 were made previous to 1876, since which time great improvements have been made in German cement. He now finds the tensile strength of an average cement, neat, in seven days, to vary from 640 to 853 lbs. per square inch.—W. F. R.

Nos. 1 and 2 were from Stettin, 3 from Wildau, 4 Hermsdorf, 5 Heidelberg, 7 Lüneberg, 8 and 12 Beckum, 9 Groschowitz, 10 Höxter, 11 Frankfort, 13 Riga (Roman cement), 14 Riga (Portland cement), 15 and 17 Alsen.

1 Cement, 2 Sand.							
Days of Immersion in Water.				Days of Exposure to Air.			
7.	30.	60.	90.	7.	30.	60.	[illegible]
strength.							
185	242	284	327	213	327	341	526
242	270	384	270	284	469	540	[illegible]
85	156	185	213	[illegible]	242	299	370
242	299	299	484	256	384	[illegible]	597
156	228	213	284	171	313	299	299
199	284	242	284	228	384	[illegible]	441
142	299	356	384	171	398	441	555
100	185	199	270	114	242	228	313
128	185	242	270	114	[illegible]	299	284
43	85	114	142	71	100	142	156
314	128	142	142	156	213	[illegible]	142
[illegible]	270	341	356	213	313	384	441
114	156	199	228	171	199	256	284
142	213	242	256	185	299	398	441
256	327	398	455	284	[illegible]	498	569
284	[illegible]	356	384	327	[illegible]	526	[illegible]
356	398	441	469	299	370	455	569
strength.							
2,261	2,290	2,916	2,958	1,749	2,432	3,072	3,143
1,408	2,205	2,859	3,101	1,380	2,773	3,186	3,399
1,380	1,835	2,205	2,631	1,408	2,005	2,489	2,845
2,261	2,802	2,830	3,044	2,389	2,773	2,987	3,418
1,607	1,906	2,233	2,347	1,579	2,091	2,404	2,475
1,835	2,091	2,347	2,432	1,977	2,290	2,503	2,589
1,721	1,835	2,077	2,247	1,835	2,233	2,333	2,389
1,451	1,607	1,764	2,005	1,707	1,906	2,190	2,020
896	1,280	1,593	1,621	[illegible]	1,252	1,522	1,721
740	967	1,067	1,195	768	1,152	1,280	1,522
1,422	1,465	1,579	1,650	1,906	2,304	2,731	2,973
1,835	2,304	2,717	2,901	1,963	2,432	2,659	3,200
740	1,067	1,451	1,785	1,109	1,522	1,963	2,390
1,522	1,949	2,062	2,261	1,721	2,347	2,582	2,745
1,493	1,707	2,091	2,389	1,764	2,176	2,517	3,072
1,849	2,418	2,916	3,527	2,105	2,917	3,399	3,755
2,034	2,745	3,101	3,485	2,660	2,987	3,357	3,641

W. F. R.

On the Improvement effected by storing Portland Cement.

By Dr. L. Erdmenger.

(Thonindustriezeitung, vol. ii., p. 306.)

Previous experiments made by the Author showed that the maximum amount of carbonic acid absorbed by dry Portland cement, under the most favourable circumstances, was 4 per cent. If, however, the bulk of cement be considerable, the carbonic acid does not penetrate into the interior, and the improvement which takes place cannot be attributed to its absorption. The time of setting is much increased by storing, especially where the cement is exposed to the air in a thin layer. When a heap of cement is stored in a dry place, the outer portions soon become more slow-setting than the inner, but their strength, especially when mixed with three parts of sand, is somewhat less, owing to the absorption of carbonic acid and moisture. A quick-setting cement showed, when fresh and tested according to the German standard rules, a tensile strength of 114 lbs. per square inch in seven days, and 158 lbs. per square inch in twenty-eight days. The increase of temperature, four and a half minutes after mixing with water, was 52°·7 Fahr. After being stored for seven months in a layer about 5 feet deep, the outer portion was found to be slow-setting, and gave a strength of 137 lbs. per square inch in seven days, and 181 lbs. per square inch in twenty-eight days. The increase of temperature which it produced when mixed with water was only 37°·4 Fahr. in fifty minutes. At a depth of 2 feet 3 inches in the same heap the cement was found, after the lapse of seven months, to possess a tensile strength of 189 lbs. per square inch in seven days, and 204 lbs. per square inch in twenty-eight days, while the increase of temperature was 48°·2 to 50° Fahr. in six minutes. Cement improves by keeping, even when carbonic acid and moisture are excluded, so that the increase of strength cannot be attributed to either of these agents. The more carefully the cement has been made, the less it is improved by keeping.

W. F. R.

Stability of Stone Structures. By W. H. Searles.

(Transactions of the American Society of Civil Engineers, vol. viii., p. 238.)

The object of this Paper is to describe a novel type of construction adopted for the piers of a railway bridge across the Presumpscot river.

The site of the bridge is just below some rapids, and the central pier carrying the ends of the 97-feet 6-inches girders consists of a couple of masonry columns, each only 2 feet square and 14 feet high. The natural stability of such columns would obviously be totally

inadequate to withstand either the rush of water, some 8 to 10 feet deep, travelling at 15 or 16 feet per second, or the retarding action of brakes suddenly applied to a train passing over the bridge; hence, to supplement the stability due to the weight of the columns and superstructure, a Bessemer steel rod, 3 inches in diameter, carried through the centre of each of the columns, was anchored to the rock below, and screwed up to an initial tension of 20,000 lbs. per square inch, so as to grip the columns to the rock independent of gravity. In the discussion on this Paper, Mr. Chanute and other engineers pointed out the grave objection to such a system from the difficulty of ensuring the maintenance of the assumed initial tension on the rod, under changes of temperature and other practical contingencies.

B. B.

NOTE.—It has apparently not occurred either to the Author or to the engineers joining in the discussion that although the bridge would probably not be washed down by the rapids, nor upset by the brakes, yet it could be very readily blown down. Adopting a wind pressure of 450 lbs. per lineal foot of truss, as given in Mr. Chanute's recent specifications for the Erie railway bridgework, the overturning moment of the wind pressure alone on each of the two columns would obviously be

$$\frac{97 \cdot 5 \text{ feet} \times 450 \text{ lbs.} \times 14 \text{ feet}}{2 \text{ columns}} = 307,125 \text{ foot-pounds.}$$

It is only necessary to add that the Author estimates the safe moment of stability of each column at 143,570 foot-pounds.—B. B.

Flexure and Transverse Resistance of Beams.

By C. E. EMERY, Ph.D., M.A.S.C.E.

(Transactions of the American Society of Civil Engineers, vol. viii., p. 149).

This Paper states that it is well known that materials like cast iron, with an ultimate tensile resistance much less than their ultimate resistance to crushing, show under transverse strain, reduced to longitudinal strain by the usual formula, much greater tensile strength than when the strains are actually applied in a longitudinal direction. Attention is called to the fact that similar discrepancies are found in the application of the theory of transverse strain to other materials, particularly wrought iron and steel; and statements are given of the experiments and opinions of Prof. Hodgkinson, Mr. W. H. Barlow, General J. G. Barnard, Mr. L. Nickerson, and others, on the subject. Curves are given, plotted from experiments of Professor Hodgkinson, Capt. Rodman, Professor Thurston, Mr. David Kirkaldy, and others, showing the increments and decrements of length due to varying strains for cast iron of different kinds, and for Bessemer steel. Equations of several of these curves have been found, and are substituted in a modified form of the ordinary equation for transverse resistance.

The Paper states that for a beam subject to transverse strain the moments of resistance of fibres at different distances from the neutral axis are generally calculated by a method due to Navier, based on the suppositions—1st, that the strains are proportioned to the elongations; and, 2nd, that the elongations are proportioned to the distances of the fibres from the neutral axis. Thus, if the distances last mentioned be represented by the variable x, this quantity finally becomes involved three times in the resulting expression, viz., once to represent the depth of the section (being advanced during integration from its differential, representing the depth of a fibre); once to represent the elongations, or the corresponding strains or unit forces due thereto; and again to give the moment of resistance of each fibre from the neutral axis, such moment assisting in balancing the external moment. It being known that the first of the principal suppositions is not in general true—that is, that the strains are not proportioned to the elongations, at least for all values to the point of rupture—it has been suggested that if the true relations between the same were included in the discussion, the well-known discrepancies would disappear. Such relations have been included in the formula in this Paper, by substituting for one of the factors, x, a function of x, showing the relations between the elongations and corresponding strains as determined by experiments; but it is found that by this means the discrepancies are only partially accounted for.

The writer claims in this Paper that the second supposition upon which the formula of Navier is founded, viz., that the elongations of the fibres are proportioned to their respective distances from the neutral axis, is also incorrect, and that when the lateral adhesion of the fibres is considered, the positions of the isodynamic curves indicate both the possibility and probability that the intermediate fibres between the axis and outer boundaries of the beam may, and do, receive more strain than that due to their positions, thereby relieving the outer fibres.

The action is illustrated as follows: If strain be applied to the centre of opposite sides of a piece of rubber, the entire central section of the rubber between the points of application of the force will be strained, the strain being greatest in a line joining the forces, and reduced on either side. If, now, forces of less intensity be applied either side of the first force, the effect will be to increase all the strains somewhat, but a portion of the strain from the original force will still be carried by parts of the section not directly in line therewith, and the fibres directly in line be thereby correspondingly relieved. The question at once arises, how room can be found for increased elongations and compressions necessary to produce increased strains, between the neutral axis and outer edge of a beam? This is evidently provided by the shape of the isodynamic curves which run from the intermediate spaces on either side of the axis to intermediate distances in the length of the beam; so an action of the kind mentioned should simply cause the beam to bend more on either side of the centre than theory

demands, and this furnishes the basis, with sufficient delicate apparatus, of experimentally testing the correctness of the hypothesis.

When the function of x, above mentioned, is in the form

$$(53) \quad y = \phi(x) = a\,x^n,$$

the equation of the isodynamic curve is

$$(60) \quad k = \left(\frac{\mathrm{Y}.b_0\,h_0^{\,2}}{m'\,(n+2)}\right)^{\frac{1}{n}},$$

in which k equals the proportion of the depth of the tensile section considered, b_0 the breadth, and h_0 the depth of such section, Y the constant strain at the variable proportional distance k, and m' the moment. (D, below, refers to the total depth of both sections.)

In support of the theory, attention is called to the fact that the shorter central isodynamic curves closely resemble the wedge-shaped piece excluded when the material parts in compression, showing a concentration of force along the general direction of the curves. Again, it appears from experiments with polarised light, that the lines of strain in glass closely resemble the isodynamic curves; and it having been shown that steel, even when soft, presents the same discrepancies of theory with experiment, for transverse strains, as cast iron, it appears probable that it is a general phenomenon for most or all materials, which has not been pointed out from the want of experiments as carefully conducted as those to which reference is made. Lastly, for the surplus strength shown by soft specimens of steel which bent very much before breaking, this theory in connection with the results of longitudinal tests will account satisfactorily; for by inspection of curve 9 it becomes evident that, after the elastic limit of the outer fibres and many of the intermediate fibres is passed, such fibres are still offering a nearly constant resistance, due to the horizontal part of the curve, while the equalisation of strain can still go on as before. The effect of an equalisation of strain between the outer and medial fibres is to give the real isodynamic curves greater inclination from the horizontal than those derived from direct longitudinal experiments. From this it appears that the increased strains due to the diagonal direction of the curves may become so important that the fibres will part at one side of the section of maximum moment, as is frequently reported.

The equations show that, both by the ordinary method and when the shifting of the neutral axis is considered, the strain on the outer fibre is expressed by an equation in the form

$$(61) \quad \mathrm{Y} = \frac{\mathrm{K\,M}}{b\,\mathrm{D}^2},$$

K as shown, reducing to a numerical coefficient. The portion of

the second term $\frac{M}{b\,D^2}$ will be recognised as equal to S in the well known formula for transverse strain,

$$(62) \quad S = \frac{L\,W}{4\,b\,D^2},$$

so from (61) it follows that

$$(63) \quad Y = K\,S.$$

When the function of x, representing the relation of the strains to the elongations, is in the form of (53) above, and the neutral axis is considered to be in the centre,

$$(64) \quad Y = 2\,(n + 2)\,\frac{M}{b\,D^2} = 2\,(n + 2)\,S,$$

so when Y and S are known, a value of n may be obtained, which in an equation of the form of (53) will give the relative strains on each fibre, with the equalisation of strain between different fibres duly considered.

In practice, equation (63) may be treated as an empirical formula, in which by ordinary theory K equals 6, but, when the other conditions mentioned are considered, is reduced to from 2·8 to 3·0 for ordinary cast iron, to about 4·7 for gun iron, and to 3·3 to 3·6 for moderately mild steel from the hammer, not annealed or tempered. It is probable that the value for wrought iron is about the same as the latter.

Evidently, for solid beams the equalisation of strain referred to must commence as soon as flexure begins, which explains the fact that the ordinary formulæ are incorrect, even within the limits of elasticity.

In an Appendix are given extended mathematical discussions relating to the flexure and moments of resistance of solid and skeleton girders according to the ordinary theory, with modifications permitting the introduction of the actual experimental relations between the strains and elongations, and providing for the consequent shifting of the neutral axis; together with a development of the equation of the isodynamic curve and of that showing the relative strains on different fibres, as given above.

C. E. E.

Cheap Well Foundations. By B. W. Blood, M. Inst. C.E.

(Professional Papers on Indian Engineering, July, 1879.)

Near Nawah, on the extension of the Rajputana State railway, the line crosses a bay of the Salt Lake, into which runs, during the rains, one of the largest feeders of the Sambur Lake, the river

draining about 100 square miles of country, and at times discharging a considerable volume of water, which will be crossed by a bridge of 40 spans of 20 feet. The bed of the lake at the site of the bridge is composed of about 3 feet of stiff clay mixed with sand, then 13 feet of quicksand, with thin beds of kunkur at intervals, till, at about 15 to 17 feet, a thick band of soft, scaly, half-formed sandstone is reached. The foundations were to be of an oval form, 13 feet by 11 feet, the lower part composed of concrete put into wells sunk to receive it. On account of the expense of a regular well steining and curbs, and the delay they would cause, it was decided to adopt a steining of sirpat grass sunk according to the system followed by the natives of the North-Western Provinces for their Kutcha wells. This steining was made of long jungle grass, formed into a hard roll, 8 to 9 inches thick, which was payed into the wells and packed coil under coil as the work went down. The internal form of the wells was maintained with great care, the base being splayed out for the last few feet, to afford a greater bearing. The wells were carried down 1 foot into the hard material, and then filled in with 12 feet of concrete made of hydraulic kunkur lime, kunkur, bajri, and sharp broken stone. This concrete sets into a mass of rock, and gives in every way as good a foundation as a brick or masonry well of the same depth. The mode above described is believed to be novel, and to be suited for those cases where the soil is not too wet to allow a well to be kept dry.

F. G. D.

Foundations of the Bridge over the Elbe at Hohnsdorf-Lauenburg, on the Hanoverian State Railway. By E. Gaertner.

(Zeitschrift des Oester. Ingenieur- und Architekten-Vereines, 1879, p. 49.)

This bridge, carrying a double line of rails, has a waterway of 1,470 feet, made up of two swings of 46 feet, three river openings of 328 feet, and three flood openings of 131·3 feet. The pneumatic process was adopted for the four river piers, and that of open well-sinking for the others. Each pier is founded upon two circular brick wells, connected by an arch below low water. The diameters of the wells are, for the pivot pier, 29½ feet; for the river piers, 26½ feet; for the flood piers, 18 feet; for the Lauenburg abutment, which was also founded on two wells, 19 feet 8 inches; and of the four wells of the Hohnsdorf land pier, the two front ones are 21 feet 4 inches in diameter, and the hinder ones 13 feet 1½ inch. The foundations of the river piers reached to about 39 feet, and of the others to about 23 feet, below low water.

The base of each well is provided with a curb, consisting of a wrought-iron shoe 16 inches deep, joined to a ring-shaped plate 1 foot broad and 0·4 inch thick, projecting inwards at right angles to the cutting edge, and forming the seat for three courses of red

beechwood rings, 3 inches thick, which overlap one another towards the interior, and are firmly bound together, screwed to the iron seat, and well coated with tar. Between the lowest wooden ring and the iron plate lies a strip of tarred felt, and on the uppermost ring is laid a coating of sanded tar, to which the mortar of the masonry unites.

On this base is built the working chamber proper, of brickwork, with a protecting rim of clinkers at the outer circumference of each of the first seventeen courses. These rise in all 6 feet 2 inches above the cutter; then follow alternating courses of stretchers and headers. Every course of the working chamber has a rim of clinkers, placed only as headers, at its inner circumference, and the courses project inwards in pairs beyond those immediately beneath, so that the chamber assumes a dome shape. Above the seventeenth course all the masonry, except the inner rim of clinkers, is of common brick. The mortar used consists of 1 part of Portland cement to 1 of sand for the lower courses and protecting rims, and 1 part of cement to 2 parts of sand for the interior masonry of the higher courses.

In the horizontal plate of the curb, holes 1·8 inch in diameter were pierced for the reception of suspension screws for lowering the foundations from the scaffolding to the river bed.

The upper end of the working chamber is formed by an iron plate 0·4 inch thick, connected by gusset stays with an oval iron faucet pipe 2 feet high, and built at a height of from 2½ to 3½ feet into the masonry of an elliptical brickwork shaft. The masonry is secured to this shoe by a number of iron cramps, 0·8 inch in diameter.

A point of great importance in the construction of these works consisted in the supply of compressed air to a chamber entirely of masonry directly after completion, and previous to the complete hardening of the mortar. Measures were therefore taken to secure the greatest possible tightness by grouting the joints, coating the inner surface with fluid cement, and, above all, by very careful execution of the brickwork.

At the wells of the first river pier the pneumatic excavation proceeded at the rate of about 2 cubic yards per hour of effective working time.

For the last two river piers a change of form was adopted; the ground plan shows two intersecting ellipses, enclosing the base of the pier; their major and minor axes measure respectively 39·7 and 22·8 feet, the length over all being 52·8 feet, giving a ground surface of 113·2 square yards. The walls are united between the points of intersection of the ellipses by a cross wall, which divides the chamber into two compartments, between which there is communication by an opening in the cross wall. Each of these compartments terminates, as before, in an oval shaft, for connection with the pneumatic excavating apparatus. The sinking of one of these piers, 34·4 feet into the ground and 43·3 feet under mean water level, occupied twenty days, including various interruptions.

The contractors received about 13*s.* per cubic yard for pneumatic excavation, and about 21*s.* per cubic yard for the preparation and placing of the concrete in compressed air; but in the case of the new design for the last two river piers, the price of excavation was raised 10 per cent., on account of the more difficult nature of the work, and the greater amount of plant required.

A. Br.

The Bridges of the Berlin-Stettin Railway in the Valley of the Oder, near Stettin.

(Zeitschrift für Bauwesen, 1879, p. 1659.)

In doubling the Stettin–Stargard section of the Berlin-Stettin railway, the opportunity was taken of substituting iron bridges for the old timber structures in the valley of the Oder. The existing wooden bridges had a total length of 1,860 yards, and the combined widths of openings for streams, &c., amounted to 1,695 yards. A careful examination of the inundations of the valley proved that it was possible to diminish these river sections considerably; and, with the permission of the authorities, the widths of openings were reduced to 567 yards. Precautions were, however, taken to spread the waters uniformly during periods of inundation, before their arrival at the bridges, so that they might flow equally through all the openings. It was determined to bridge each stream by a single span, so as to avoid reducing the bed by piers, and also in order to avoid the cost of foundations, which would have had to have been laid under an average depth of 36 feet of water.

Foundations.—The soil in the valley of the Oder, in the uppermost layers, consists of peat and turf of varying thickness, and of sand with veins of clay running through it; the solid ground fit for foundations lies, on the average, 25 feet below the surface of the meadows. For the foundations of all the piers a system of piles was chosen, the heads of the piles being connected by cross beams; in this way the timbers of the old bridges were utilised. In the case of the large piers, the soil was excavated between the piles to the depth of 3·28 feet, and its place filled by a layer of concrete; also the piers were surrounded by sheet piling, and were protected from underwashing by heaps of large stones. The small piers had no sheet piling, and their pile foundations were not strengthened by concrete. Above the piles the piers were constructed for 1 foot in granite, and thence upwards in brickwork. The coping stones and foundations of the girders were laid in basalt lava.

The foundation of the round swivel pier of the Kahnfahrt bridge consisted of a masonry cylinder, 26 feet in diameter, resting on a ring of segmental plates 0·4 inch thick, and 28 feet in diameter, connected together and supported by three circular angle irons.

The great diameter of the cylinder permitted of its being sunk by a vertical dredge, and when finished was only 0·78 inch out of its right position. The lowest layers were filled with concrete, above which came brickwork set in pure cement mortar, to a height of 11·5 feet. The side walls of the cylinder were four bricks in thickness.

The long piers of the flood openings were founded on brick wells of an oblong section. The lowering of these caused much trouble. Owing to the want of homogeneity of the soil, they often assumed an oblique direction, and were with difficulty brought plumb again. The long, straight side walls were unable to bear the pressure of the earth, and had to be stiffened on the inside in such a manner that but little space was left for working by hand, and the vertical dredger had to be brought into requisition. For the shore piers, in order to avoid these difficulties, cylinders of elliptical section were chosen; but they also gave great trouble.

The Ironwork.—The small flood openings of the bridge were spanned by ordinary plate girders. For the smaller streams Schwedler girders were chosen; and for the larger ones girders with elliptical top and straight bottom booms. These latter were of an unusually light construction. The swing bridge over the Kahnfahrt is similar in construction to that over the Parnitz; but in some few respects improvements have been adopted. Transverse girders of lattice-work were used instead of plate girders; the former are easier to repair, and admit of readier access to the rollers and their standards.

When tested, the Zeglin bridge suffered a maximum deflection of 1·6 inch, or $\frac{1}{2244}$ part of the total span; the permanent deflection was on 0·12 inch. The maximum deflection of the Kahnfahrt bridge was 1·6 inch, or $\frac{1}{1854}$ part of the total span, and the permanent set was 0·23 inch.

The total cost of the section of the line from the goods station at Stettin to Finkenwalde, 2½ miles in length, was about £131,000; of this sum about £80,900 was absorbed by the bridges, as shown in the following table:—

	Foundations.	Superstructure.
	£	£
1. Bridge under siding	10,400	7,650
2. Little-Reglitz bridge	3,400	5,750
3. Brunckenstrom bridge	3,650	3,700
4. Kahnfahrt bridge.	11,150	12,450
5. Zeglin bridge	6,800	15,950
	35,400	45,500
	£80,900	

G. C. V. H.

Superstructure of the Glasgow Steel Bridge.[1]

By Gen. W. Sooy Smith.

(Proceedings Engineers' Club of the North West, June 1879.)

The bridge consists of five spans of 311 feet each from centre to centre of the end pins of the Whipple double intersection pattern with inclined end posts. In three the platform is carried by the lower boom, and in the other two by the upper. The trusses are 36 feet in effective depth, and are divided into seventeen bays. After many experiments and tests it was found that the Hay steel could be produced of uniform composition and quality, tough and ductile at ordinary temperatures. In the sizes actually used it was found to have an elastic limit of 48,000 to 55,000 lbs. per square inch, with an ultimate strength from 80,000 to 100,000 lbs. per square inch. The elongation before breaking was from 10 to 15 per cent., and the reduction of area at the section of fracture 10 to 30 per cent. It withstood shocks better than wrought iron, and was not perceptibly weakened with repeated strains. This steel could be welded soundly, but not with the same certainty as wrought iron; it was also more impaired than the latter by upsetting.

Three methods of making an eye bar were referred by the Author to the manufacturers in his order of preference. 1. The bar to be rolled in a universal train in one piece, with enlarged ends, which could be hammered down and finished into eyes without welding or upsetting. 2. The eye bar to be hammered at once from a billet into the finished shape. 3. A bar of the full width of the eye to be taken, and the body of the bar reduced under the hammer, finishing the eye of the requisite size and shape by the same operation. The last method was tried with satisfactory results, but the completion of Andrew Kloman's universal mill rendered the trial of the other method unnecessary, and the bars produced by him were found equally strong in the eye as in the body.

The long main and counter braces were made in two lengths, united by pins and cover plates; the pins also held the ends of a line of horizontal rods carried from end to end of each truss, to prevent the buckling of the upright posts. The usual top and bottom lateral bracing is employed, and in addition the longitudinal rail girders are braced together in the form of a Warren girder laid on its side. At 21 feet from the foot of each post is a cross strut, uniting it to the one opposite, and braced to the corresponding transverse member, immediately above it, of the top lateral bracing. The rail girders are made strong enough to carry the heaviest load, on two bays, so that in the event of the failure of one of the cross girders, the load would be transmitted to that

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[1] A description of the substructure of this bridge will be found in the Minutes of Proceedings Inst. C.E., vol. lvii., p. 328.

at the next intersection; and it was with this object in view that the double intersection pattern was adopted for the main girders. All the tension members of the bridge were carefully annealed, this process relieving the metal of any internal strains, and increasing its toughness and ductility, but at the cost of a slight diminution in the elastic limit and ultimate strength. The five spans were each tested with a load of 100 tons—made up of a locomotive with tender and two heavily-loaded trucks, placed at the centre—when the deflections varied from 1·56 to 1·80 inch. Each span weighs about 100 tons less than an iron truss of the same strength; full advantage, however, is not taken of the superior strength of the steel. Taking the elastic limit of the steel at 48,000, and that of iron at 24,000, the Glasgow bridge is stronger than most iron bridges of its class in the proportion of $\frac{1}{2}$ to $\frac{1}{3}$, the maximum strain being in this bridge $\frac{1}{3}$ its elastic limit, while in iron bridges it is usually $\frac{1}{2}$.

The bridge was completed in one year from the commencement of the work, and was opened for traffic on April 26, 1879. When exposed to a heavy gale at right angles to its length, no lateral motion was perceptible.

A. T. A.

On the Fixing of Fang Bolts. By A. J. Susemihl.

(Organ für die Fortschritte des Eisenbahnwesens, 1879, p. 166.)

The object of this note is to direct attention to the proper mode of inserting fang bolts, to fasten a Vignoles rail on its sleeper. The hole for the bolt should never be bored perpendicularly to the sleeper, as is usually done. In that case the head of the bolt only bears just at its edge on the foot of the rail; the rail, therefore, in working sideways, acts as a lever to bend the bolt. This it soon accomplishes, and then the edge of the rail-foot presses against the shank of the bolt, bends it still further, and makes a loose fastening. The hole should be bored perpendicularly to the inclined upper surface of the rail-foot; the underside of the bolt-head then rests fairly on the rail-foot, and, by screwing up, the bolt may be made to grip it with any desired force. In June 1877, the Author fastened a stretch of track on the inside of the rail with fang bolts thus placed, and on the outside with dog spikes. In February 1879 this track had not required the smallest attention in any way, and still seemed perfectly good. All cutting of the rail into the neck of the bolt is thus prevented, and the Author considers the system superior to any fastening with spikes alone.

W. R. B.

The Arad and Körös Valley Standard-gauge Provincial Railway.

By B. Boros.

(Magyar Mérnök-és Épitész-Egylet Közlönye, vol. xiii. pp. 327, 372.)

This appears to be the first railway in Hungary which has been projected, financed, built, and worked by those immediately interested in it; and has dispensed with the State guarantees.

Though the line is only 38 miles in length, it appears to have solved a problem of national importance. Russia, the United States, and even Australia, have been getting the better of Hungary in the produce markets of Europe. Trunk railways there are few, and they stop short just where their extensions are most wanted. In these vast plains, covered with the richest of soils, a mile of proper road would cost three times the amount for which a railway like this may be established.[1]

The most notable particulars in the Paper are the following: 252,000 cubic yards of earthwork, and 1,500 cubic yards of rock-blasting, did not cost more than £4,720; bridges and culverts less than half this sum. For ballast, shingle was obtained from Arad. The sleepers are of oak. Two-thirds of their rails are steel; their uniform weight is 23·65 kilogrammes per lineal mètre. The company own four locomotives and sixty-eight vehicles, serving twelve stations. And the whole cost of construction does not exceed £2,800 per mile. More remarkable, however, are their working results for the first complete year, 1878: with no more than seventy-two thousand passengers (carried an average distance of a little more than half the length of the railway), and no more than 72,700 tons of goods (average passage 28 miles), forwarded much more cheaply than by the great railways, 9 per cent. nett profit was made.

Though the co-operative nature of the company, and the lowness of the prices goes some way to explain this rare success, great credit is due to the organisation of the staff. The telegraph was laid before the earthworks were begun. Penny-wise economy in the number and the salaries of their engineers was avoided. The earthworks were not stinted, so that there might be no steeper gradient than 1 in 300. But for the earthworks only side-transport was necessary; side cuttings were made for the embankments; and the excavated material from the cuttings was removed by the proprietors over their fields. The Author shows the great advantage of such companies working their own railway, and on no account farming it to the neighbouring great companies. The locomotives all have six coupled wheels and separate tender, to save maintenance. The speed is strictly kept down to 14 miles an hour; and to ensure this, velocimeters of the Petri patent,

[1] This statement has been practically tested in detail, and found to be literally true.—B. S.

which not only show the speed continuously, but record it graphically, are attached to the vehicles. The stock wanted in excess of that belonging to the company is hired from the large companies. The greatest care is taken to ensure as full loads and as quick loading and emptying as possible. To this end granaries have been built at their stations, which are hired to the customers, who may there collect and manipulate their grain. As an unheard-of thing in the Alföld (lowland) of Hungary, the company has connected the twelve nearest towns and villages by roads with the stations; by which means not only traffic is increased, but also maintenance reduced. Instead of watering stations, three wells are provided, and Friedmann ejectors are used, which cost only £80 a-piece, and prove economical in working. For repairs of stock only one small shop is provided, and much is saved by sending to the large companies vehicles requiring heavy repairs.

B. S.

The New Railway Station at Hanover.

(Deutsche Bauzeitung, 1879, p. 357.)

This station accommodates the traffic in connection with the main lines between Berlin, Cologne, Hamburg and Cassel, together with the branches to Bremen and Altenbeken. Facing the Ernst-August Platz are three distinct blocks of buildings; the central or reception building containing the various waiting-rooms, luggage offices, vestibule, &c., and those at the sides the manager's offices and postal service respectively, the intervening arched spaces, 98 feet 6 inches in breadth, being for the public street traffic. At the rear of the central block is the station shed, 550 feet long, covered by a wrought-iron roof in two longitudinal main bays, each of 122 feet span, intercepted at their mid-length by a transept of 126 feet span. These roofs spring from iron pillars, 22 feet 4 inches in height above the platform level; the central portion is glazed, and the remainder covered with corrugated sheeting. Between the main longitudinal bays there is an uncovered space of 30 feet 2 inches in breadth, over the lines devoted to goods traffic; there is also, between the bay nearest the central block and the latter, an inclined roof of 14 feet 7 inches span, giving altogether a total width of 288 feet 9 inches for the station shed.

There are seven lines of rails for passenger traffic, and three for goods, luggage, postal service, &c. Access to the various platforms is gained by steps ascending from subways, of which there are three for passenger use, 13 feet 2 inches to 23 feet in breadth, and two for goods and luggage traffic, the last being provided with hydraulic lifts; in addition to these, there is a special subway from the postal service building, with inclined planes leading to the platforms. It is intended to erect on the main platform a light iron construction, to serve as refreshment and retiring rooms for through passengers. In the central block, which is 550 feet long,

and from 69 feet to 88 feet 6 inches deep, is a vestibule 100 feet 9 inches long, 82 feet 6 inches broad, and 59 feet 8 inches high, there being five doorways communicating with the street, and others at the sides and rear, the latter leading to a corridor from which diverge the various subways. Light is obtained from three lofty round-topped windows, and an upper row of lights in the façade, and corresponding ones at the rear looking into the station hall. In this vestibule are the booking and telegraph offices. The floor level in general is 1 foot above the street, and 12 feet 2 inches below rail level. The building is warmed by hot air. A detailed description is given of the architectural structures, which partake of the Renaissance and Gothic orders, and also of the style of decoration. The walls are in brickwork of two colours, principally light yellow "Backstein," variegated with courses of red from the Greppiner works; the plinths, mouldings, exterior architraves, &c., are of grey Mehler sandstone. The roof is slated. The cost of the reception building will be £62,500, or £14 per square yard of area; and that of the station shed £25,000, or £1 10*s*. per square yard of area.

D. G.

The New Railway Terminus at Metz. By Hr. Schubler.

(Deutsche Bauzeitung, 1879, p. 287.)

Metz ranks next to Strasburg in point of importance as a railway centre. For the enlargement of the old terminal passenger and goods station, and the remodelling of the outer or through station, so as to include a marshalling and locomotive depot, the sum of £150,000 was required. The present Memoir describes only the new terminus.

In the building forming the main front, and at the head of the station hall, are situated the waiting and refreshment rooms, also two vestibules for arriving and departing passengers; and in the east and west wings, which extend on either side of the hall for about half its length, are the post and telegraph departments, on the ground floor; and above these, in the west wing, are traffic and goods managers' offices; whilst in the east wing are the superintendents', station masters', refreshment contractors', &c., quarters. The stone used in the construction of these buildings is a yellowish limestone, obtained at Jaumont, and similar to that employed in the most important edifices of Metz.

The main hall is 492 feet long, and 160 feet 9 inches clear breadth, with a wrought-iron roof in two bays of parabolic curvature, each bay being 79 feet 9 inches span, supported at the sides by the interior walls of the east and west wings before mentioned, as far as they extend, and beyond that by a massive wall on the one side and cast-iron columns on the other; a row of cast-iron columns, each 29 feet 6 inches high, also runs down the centre of the hall.

There are a central and two side platforms, serving for the arrival and departure trains of the Strasburg, Luxemburg, Frouard, and Forbach traffic, and a fifth short platform for Verdun trains is provided at the south-west end of the hall. A steam traverser connects, directly, the station lines with the outside lay-bye sidings. The cost of the terminus, exclusive of expenses of superintendence, amounted to a sum of £54,000, of which £18,000 belong to the hall. The main front and wings, including goods shed, from ground floor to eaves, cost 18*s.* 9*d.* per cubic yard, or £7 18*s.* 10*d.* per square yard of ground area, and the hall £1 19*s.* 4*d.* per square yard. The whole of the masonry amounted to 23,805 cubic yards, including 5,167 cubic yards of ashlar.

The decorative work cost £700.

The above amounts include gas, water, and heating arrangements, but not furnishing waiting-rooms.

D. G.

New Arrival Shed, Northern Railway of France.

(Annales Industrielles, 20th July, 1879, col. 80.)

The new arrival shed at the arrival yard of the Paris terminus of the Northern Railway of France, was erected in 1877. The width is made up of two bays, of 75 feet 3 inches span, and one of 14 feet 6 inches span; making together a width of 165 feet. The length of the shed is 227 feet 9 inches; and the total covered area amounts to 4,296 square yards. The roof is supported on twenty-four cast-iron columns, three in the width, placed in pairs in the end row, carrying principals placed at centres 10 mètres, or about 33 feet, apart. To make sufficient provision for ventilation, an opening has been left in the glass roofing, directed eastward, the prevailing winds being from the north or the west. The wall is 19 feet 8 inches high, and about 335 feet in length. The cost for earthwork and masonwork had amounted to £192; granite edging, £52; woodwork, £1,800; covering, £700; cast-iron and wrought-iron work, £5,040; painting and glazing, £608; gas, about £200: total cost, £8,592. The surface of the court is taken at an area of 4,296 square yards, and the total cost has amounted to £2 per square yard.

D. K. C.

Steam-Traverser for Railway Stations. By M. Bernard.

(Revue Générale des Chemins de Fer, May 1879, p. 378.)

The steam-traverser consists of an ordinary traverser, coupled laterally to a steam-propelled truck or van running on the same transverse lines of rails; the steam is generated in an upright boiler, and works a pair of cylinders, with toothed gearing to

drive the wheels of the truck, and reversing gear, so as to traverse in either direction. The total combined weight amounts to 21½ tons, and the traverser can be easily moved with a load of 25 tons.

The steam-truck is fitted with a rope-drum and a capstan, which can be worked by steam-power, and is employed in moving and sorting wagons in a goods station. It is capable of moving up a lot of from fifteen to eighteen empty wagons. At the Saint-Sauveur station, on the Northern railway of France, it was found by observation that, by means of the steam-traverser, an average of two hundred and forty wagons per day of seventeen working hours, or fourteen wagons per hour, were marshalled. Of these two hundred and forty wagons, one hundred and thirty were shifted from one line of rails to another. On busy days, two hundred and sixty wagons have been moved per day of seventeen hours.

The first cost of the steam-traverser was £1,120; and adding the cost of the transverse way, 196 yards in length, £720, with ballasting, &c., £160, the total first cost amounted to £2,000. The working expenses amount to 22*s*. 2*d*. per day of seventeen hours. The comparative cost for the same work done by horse-power, amounts to 28*s*. 6*d*. per day. It is thought that, with an engine so arranged as to be easily shifted from one traverser to another, the serviceableness and economy of the steam-traverser would be augmented.

D. K. C.

New Carriage Workshops for the Northern Railway of France.

(Annales Industrielles, 6th July, 1879, col. 16.)

The new workshops recently completed at St. Denis, for the construction and the repair of railway carriages, consist of shops for mixing and filtering oils, and grinding colours; the engine- and boiler-house, a tool-shop, ten smiths' shops, an ordinary smiths' shop, and a store. The smiths' shops are constructed of iron. The minimum clear height is 11 feet above the floor, and the ruling length of the shops is 65½ feet inside. The total area covered by the workshops amounts to 2,054 square yards. The cost of the individual shops had varied from 83*s*. 7*d*. per square yard, for the oil shop, with a basement floor, to 46*s*. 8*d*. for the smithies. The total cost of the works had amounted to £7,664, averaging 75*s*. per square yard of horizontal area.

D. K. C.

On Locomotive Fire-boxes lined with non-conducting material.

By S. VERDERBER, Inspector-General of the State Railways of Hungary.

(Organ für die Fortschritte des Eisenbahnwesens, 1879, p. 172.)

The water used on the Hungarian State railways is very detrimental to the locomotive boilers, especially the fire-boxes, in con-

sequence of the great quantity of scale which it throws down. In studying the subject, the author became convinced that the only complete cure for the evil was to suppress the water space in the fire-box altogether. Such an attempt was in contravention of the accepted fact that, of the total heat imparted to the water, much the larger part comes through the fire-box, and only a small part through the tubes. The author, however, considered this to be due to the following causes: (1.) Many of the tubes are not traversed by the hot gases. (2.) The temperature of the gases diminishes as they advance in the tubes. (3.) Above all, about half the available heat has already been abstracted by the fire-box before the gases enter the tubes at all. There seemed no reason to suppose that, with gases at the same temperature and density, the tubes would absorb any less heat per unit of surface than the fire-box. Hence, if the gases could be turned at their full heat into tubes of proper dimensions, the fire-box would be a superfluity. This conclusion was confirmed by the boiler experiments on the Northern railway of France given by M. Couche ("Matériel roulant &c.," vol. iii.), and by a special experiment made with an existing engine. In that case an inner casing of sheet iron, lined with fire-clay, was inserted within the fire-box. Between this casing and the walls of the fire-box a space was left of about 2½ inches, and through this space air was brought from the outside to the fire, by which means the temperature when the engine was running was kept at about 176° F., or half that of the water in the boiler. This engine worked a passenger train between Budapest and Miskolcz for about six weeks; and the water evaporated per lb. of coal was found to be about the same with the casing as without it. Thus, even with the present construction of boiler, it was shown that the fire-box was unnecessary. The fire-clay lining, thus cooled from the outside, did not appear to have suffered in the least from the heat. Another experiment was then made with a six-coupled goods engine, 36 tons adhesion weight, the fire-box of which was out of repair. The inner fire-box was taken away altogether, and the end of the barrel completely closed by a tube-plate flanged inwards, the tubes thus retaining their old length. Within the fire-box shell was inserted a casing of ⅜-inch iron, lined with fire-clay about 1½ inch thick. The lining was held in place by small hooks riveted to the casing. The boiler fittings were of course re-arranged, and the engine was then tried with a train of thirty-seven empty wagons. When standing, after a run of 17 miles, the tube-plate suddenly began to leak so heavily as to extinguish the fire. The plate was found to be bulged, and half the tubes loose. This was made good, but the same accident happened time after time. The cause was found to be that the flange of the tube-plate was not exposed to the fire, and the plate could not therefore expand freely outwards. The effect of the heating was therefore to expand the plate inwards round the tube-holes, thus contracting the tube-ends. The subsequent diminution of heat, when the engine was standing, caused the plate to contract, and the tube-holes there-

fore to get larger again; but the tube-ends did not follow them, and thus leakage began between the two. To remedy this, another similar engine (No. 104) was fitted up with a solid tube-plate made in two pieces. The upper part was flanged inwards, or away from the fire, all round; but the lower part, which actually contained the tubes, was flanged outwards along the top, and outwards round the bottom only, where the flame had free access. This engine has been in regular working since May 1878. For two consecutive months it was tried against another engine (No. 19) of the same class, but with an ordinary fire-box. The results were as follows:

	No. 104.	No. 19.
Kilogrammes of coal used per hundred tonne-kilomètre .	5·93	5·59
Kilogrammes of water evaporated per kilogramme of coal .	4·55	4·62

The difference between the two is thus represented by about 1½ per cent. only.

The following points are noted as to the working of engines with non-conducting fire-boxes.

(1.) The blast-pipe must be smaller, because the escaping gases are much hotter, and therefore require less urging.

(2.) The first third of the barrel now generates the steam which in ordinary engines comes from the fire-box, and on this part the boiler mountings are placed. Hence the cleaning of this part must be more careful and thorough; a man-hole underneath is found to be of great service.

(3.) The quantity of water in the boiler is reduced, and therefore the water-level falls more rapidly if the feed ceases. A small continuously working injector is the best feeding apparatus in these circumstances.

(4.) The fire-box in No. 104 has a sheet-iron casing, and the interval, about 2 inches, is packed with slag-wool. The surface is so cool that the hand can be borne upon it, and the escape of heat is thus considerably less than with ordinary fire-boxes.

(5.) The fire-box is made like an ordinary arched furnace, built up with fire-brick. It has lasted excellently for five months. An iron furnace, lined with fire-clay, enables steam to be got up more rapidly, but is costly and liable to crack.

The cost of thus fitting up an engine whose fire-box is worn out is about £25, whereas the replacing of the fire-box costs £100 to £200.

W. R. B.

Four-Coupled Express Locomotives in France.

By M. Baude.

(Bulletin de la Société d'Encouragement, 1879, p. 290.)

The older stock of express locomotives on the main lines of railway in France, consisting for the most part of engines of the Crampton type, have been superseded in recent years by engines

having four-coupled wheels, of large diameter. The regulation speed of 48 miles per hour, occasionally, in consequence of delays, attains the rate of 60 or 62 miles per hour; for such high speeds large wheels and much adhesion became necessary.

The leading particulars of the four-coupled express engines of six main line railways in France, are abstracted in the annexed Table:—

Particulars.	Six-wheeled Engines.			Eight-wheeled Engines.		
	Eastern Railway.	Southern Railway.	Western Railway.	Lyons Railway.	Orleans Railway.	Northern Railway.
	Sq. Feet.	Sq. Feet.	Sq. Feet.	Sq. Feet.	Sq. Feet.	Sq. Feet.
Area of grate . . .	25·64	18·40	18·81	23·00	17·42	24·83
Number of flue-tubes	206	180	156	164	177	201
	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
Diameter of tubes outside	1·93	1·97	1·97	1·97	1·89	1·77
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Length of tubes . .	11·5	11·5	12·6	16·2	16·4	11·5
	Sq. Feet.	Sq. Feet.	Sq. Feet.	Sq. Feet.	Sq. Feet.	Sq. Feet.
Heating surface, fire-box	91·36	98·04	75·02	96·75	113·95	100·72
Heating surface, tubes calculated on their external diameter .	1192·50	1063·28	1014·26	1365·46	1434·70	1069·09
Do. do. total	1283·86	1161·32	1089·28	1462·21	1548·65	1169·81
Number of wheels .	6	6	6	8	8	8
Number of coupled wheels	4	4	4	4	4	4
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Length of wheel-base.	17·5	17·7	14·4	19·3	18·7	20·7
Diameter of driving-wheels	7·54	6·85	6·26	6·89	6·56	6·89
Position of cylinders.	outside.	outside.	inside.	outside.	outside.	inside.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
Diameter of do. . .	17·7	16·9	16·5	19·7	17·3	16·9
Length of stroke . .	25·2	23·6	23·6	25·6	25·6	24·0
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Weight of engine, empty	35·7	34·1	33·0	40·8	37·7	38·4
Weight of engine in order. . . .	38·5	37·5	36·0	44·8	41·8	41·6
Weight of engine for adhesion . . .	27·0	26·0	24·9	25·2	24·9	27·2
Weight of tender empty	11·4	12·7	11·7	15·8	11·2	10·6
Weight of tender full	23·9	24·7	21·5	30·0	24·2	21·6

The Orleans railway, in 1867, introduced four-coupled large-wheel engines, with six wheels. The fire-boxes were overhung

beyond the coupled axles, in order that the wheel-base might be limited to suit the curves of the Périgord line. But, in 1876, when higher speeds were practised, M. Forquenot introduced a fourth pair of wheels behind the fire-box, for steadiness; and applied double-incline bearings on the extreme axle-boxes, to facilitate the passage of curves. The engines of the Lyons railway are similar to those just noticed. In the engines of both lines, flue-tubes over 16 feet in length are used. The Author is of opinion that no material gain is effected by extending the length of tubes beyond 11 or 12 feet. The engines of the Western railway have a relatively short wheel-base—14 feet 5 inches—the hind axle being placed under the fire-box; the cylinders are inside, and the cranks for the coupling-rods are keyed on the axle, in the same radius as that of the corresponding inside cranks. The comparatively small fire-grate is sufficient for the combustion of the English coal which is imported for the service of the railway. The crank-axle, on Martin's system, is made straight in the middle, but is bent at each end to form a crank, the pin of which is extended and let into a boss on the wheel, where it is keyed. The frame is outside, with a central longitudinal plate and bearing for the crank-axle.

On the Northern railway, engines of four cylinders, to work two pairs of driving-wheels independently, without coupling-ends, were tried, and were abandoned in 1868. The engines now constructed have eight wheels, of which four are placed in a bogie in front; the hind coupled-axle is placed under the fire-box. On the Eastern railway, on which the Crampton express engine is still employed, the four-coupled engines are arranged as nearly as possible on the same general design as the Crampton engine. The boiler has been elevated, and the fire-box extended over the hind axle, for the combustion of coal slack, the supply of which is obtained near at hand, from Belgium and from Prussia. The driving axle is behind, as in the Crampton engine; the driving wheels, 7 feet 6½ inches in diameter, are the largest of all the wheels above tabulated. To facilitate the passage on curves, the leading axle is permitted to have lateral play, subject to the resistance of lateral springs, which increases as the axle diverges from its central position. Another system of lateral play, much employed in France, consists of two blocks of steel over the axle-box, each of which is formed with double inclines, crossing each other, and reaching from side to side of the blocks. On the Southern railway, likewise, the engines are designed on the Crampton arrangement, having the driving-wheels behind the fire-box.

In conclusion, the Author remarks that, generally, iron is preferred as the material of the boiler, and copper for the fire-box; that there is no absolute ratio between the grate area and heating surfaces and sectional area of passages; and that the useful limit of pressure appears to be attained with 10 atmospheres of steam-pressure.

D. K. C.

Experiments made on the Northern Railway of France with Chiazzari's Injector Pump. By M. PAKYNE and E. MACLÉ.

(Revue Générale des Chemins de Fer, 1879, p. 445.)

The injector pump of Signor Chiazzari, chief inspector of the Alta Italia railways, consists of a working barrel, containing a piston having a very thick piston-rod, so that the annular area at the piston-rod end is much smaller than the full area at the other side of the piston. The piston is driven by any convenient means, say from an eccentric, or, as in the engine illustrated, by a lever worked from the coupling rod of the driving and trailing wheels. There are four ball valves, one suction, and one delivery, at each end of the pump; water from the tender is received into the annular space round the piston rod, and delivered through a bifurcated passage, surrounding the base of the air-vessel, to the other end of the pump, where it falls through a perforated plate and enters the larger end of the pump, in company with a portion of the exhaust steam, the difference in areas on the two sides of the piston permitting of its thus feeding water raised to a temperature of say 186° F. A theoretical calculation is given, showing what the saving ought to be, from mixing certain volumes of the exhaust steam with the feed water; and the details of two comparative experiments, one with a goods engine and the other with a 60-HP. stationary engine, are added.

The experiments on the locomotive were at first greatly interrupted by the knocking of the pump, but this was got over by enlarging the section of the passages and altering their form. Eight comparative trips were made with coal trains between Creil and Ermont, a distance of 33 miles. Each train consisted of forty-five wagons, together carrying 440 tons + 220 tons, the weight of the wagons themselves—or a total of, say, 660 metric tons. The results, as regards water fed into the boiler, were as follows:— When working with Chiazzari's injector pump, 1,296 gallons were consumed, and with the ordinary injector 1,502 gallons, thus showing a measured saving in water of $\frac{1}{7\cdot 3}$; but in spite of this economy of water, and the fact that the water entered the boiler at a temperature of about 186° F., the Authors were unable to discover any economy of coal whatever during the five months while the trials were being carried out. They say that the injector pump never gave any trouble after it had been fairly started and the difficulty of the originally small passages had been overcome. The chief objection they see against it in regular work is, its liability to become furred up by the deposit of salts contained in the water; and they conceive it is much more open to this objection than the ordinary injector, as the heating of the water takes place so suddenly, and the precipitated particles have more favourable opportunities for depositing themselves

undisturbed, than in the case of the ordinary injector. In the trials with the stationary engine, the same trouble was met with at first as in the locomotive, owing to the knocking of the pump. This, however, was remedied by enlarging the passages. The same fuel was used during the whole of the trials; and the mean results for the months of February and March 1879 were, when working with Chiazzari's injector pump, 2,734 gallons of water and 1·774 kilogrammes of coal; working with the ordinary injector, 3,123 gallons of water, and 2·092 kilogrammes of coal. When the injector pump was at work, the feed water was delivered at a temperature of 186° to 190° F. The results of the trials with the stationary engine show a saving of $\frac{1}{6 \cdot 7}$ in fuel, and a mean of $\frac{1}{6}$ of water.

D. HA.

Compound Locomotives for the Mètre-Gauge.

By A. MALLET.

(Revue industrielle, vol. x., p. 335.)

The compound system of working, carried out [1] by the Author in the locomotives of the Bayonne and Biarritz railway, has since been applied by him also to six-wheeled coupled tank-engines on the mètre-gauge railway from Haironville to Triaucourt, in the department of the Meuse, a line running alongside a high road, and thus presenting gradients as steep as 1 in 33, and curves as sharp as 160 feet radius, with some even of 115 feet only. At these places the boiler steam is admitted direct to both cylinders by means of the starting valve, for obtaining the utmost tractive power.

A special feature in the design of these engines is that the two link-motions are arranged to work independently of each other when required, so as to cut off at a different point in the two cylinders, for obtaining the best efficiency in compound working; while at the same time both are reversed together by a single movement. Each link-motion has a separate weigh-shaft, the two shafts being in line: that for the large cylinder is worked by the nut of the reversing screw; that for the small cylinder by the ordinary hand-lever shifted into different notches of a toothed sector, which is itself connected with the nut of the reversing screw. Thus the reversing screw shifts both links together; while the link of the small cylinder is shifted independently to any different grade by the hand-lever.

The wheels being only 2 feet 5¼ inches diameter, the mechanism is brought down very close to the ground. The ordinary front rail-guards are therefore replaced by a transverse channel-iron bar,

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. li., p. 314.

fixed beneath the buffer plank, to act the part of the American cow-catcher. The wheel base is only 5 feet 6 inches; and the axle-boxes of the leading axle are made with inclined planes for lateral play. There are only three bearing springs, one at each side between the middle and trailing axles, and one transverse over the leading axle. Combined central draw- and buffing-gear with spiral spring is employed, after the Norwegian fashion. Five of these engines have now been running eighteen months, their principal dimensions being as follows:—

Fire-grate area	7·0 square feet.
Heating surface { fire-box . .	34·4 "
Heating surface { total . .	354·1 "
Steam pressure	140 lbs. per square inch.
Diameter of small cylinder . .	8·66 inches.
" large " . .	13·58 "
Length of stroke of pistons . .	15·75 "
Weight of engine, empty . .	12½ tons.
" " in working order	15½ "

When working direct, with full boiler steam in both cylinders, the engine can take a train of 60 tons up an incline of 1 in 33 at low speed.

A. B.

On the Limiting-Weight of Trains on Steep Gradients, and on Traction by the Rack-Rail and other Systems.

By K. Müller.

(Organ für die Fortschritte des Eisenbahnwesens, 1879, p. 161.)

The heavy cost of working steep gradients is due not only to the increased expense per train-mile, but also to the limit they impose on the weight of trains. Thus the cost per train-mile on a gradient of 1 in 40 is to that on a gradient of 1 in 100 in the ratio of about 1½ to 1; but the cost per ton-mile is in the ratio of 3 to 1. Taking the full working strain on the couplings at 6½ tons, and the ordinary train resistances at $\frac{1}{250}$ the weight, or 9 lbs. per ton, the Author has calculated the train weights required to produce this strain on gradients ranging from the level to 1 in 25. The weight on the level is 1,625 tons, which falls suddenly to 464 tons on a gradient of 1 in 100; but from thence it diminishes slowly to 271 tons on 1 in 50, 191 tons on 1 in 33, and 148 tons on 1 in 25. It appears, however, that the loads hauled in practice on steep gradients are considerably below those given by theory —*e.g.*, on the Semmering incline of 1 in 40 the maximum load taken by an eight-coupled engine is 160 tons, whilst the Author's table gives 224 tons as the load admissible; so that the limit of haulage seems far from being reached. To examine the causes of this, the Author discusses the various classes of locomotives, and their weights to give adhesion sufficient for the full strain

of 6½ tons. With tender-engines he shows that the joint weight of engine and tender must be nearly 80 tons, even on a gradient of 1 in 100; so that such engines are only fitted for lines whose ruling gradient is 1 in 80 at the outside. Attempts to utilise the weight of the tender for adhesion have not been thoroughly successful, at least on main lines, although theoretically the advantage thus gained would be great. This class may be divided into simple or tank engines, and double engines, such as the Fairlie system. In contrast to both these classes are the rack-locomotives, in which the weight has no direct relation to the tractive force. It is found, however, that it has a relation to the speed and tractive force combined, which is expressed by saying that the engine must have a weight of about 0·37 ton for each foot-ton per second of work done in traction. Hence, if the engine is to be light the speed must be small, and then gearing must be employed to prevent the piston speed from being too low. Taking the speed at 5 miles an hour (which is about the average of the Arth-Rigi and other railways), it appears that the weight of the locomotive to give a pull of 6½ tons is about 18 tons, irrespective of gradient. Such an engine is not out of place even on slight gradients, provided the speed be small. Where greater speed is required, the type is used which can be worked either as a rack or an adhesion engine, according to circumstances. In these engines the ordinary or adhesion wheels may either be coupled to a wheel upon the rack shaft, or one pair of adhesion wheels may be driven direct by the engine, and the rack shaft and the other pair of wheels may be connected with them. These arrangements, however, are only fit for narrow-gauge and secondary lines. For main lines the rack and the adhesion gear must be kept independent. The Aarau engine at the Paris Exhibition accomplished this by an arrangement which enabled the crank shaft to be thrown into gear with the rack shaft or with the driving axle at pleasure. The ratio of gearing was different, so that the speed, which was 12 to 15 miles an hour with the adhesion, was reduced to 5 miles an hour with the rack. Another method is to have one pair of cylinders for the adhesion wheels, and another for the rack wheels. A tank engine of this construction, weighing about 35 tons loaded, would give about 4 tons pull by adhesion, and 8½ tons with the rack, which latter would be sufficient to take a train of 120 to 150 tons up a gradient of 1 in 20.

Tables are given of the quantity of coal required, with each class of engine, to raise 100 tons 100 mètres high upon gradients from 0 up to 1 in 3. The result is that the figure for the joint rack-and-adhesion engine falls from 154 on 1 in 200, to 108 on 1 in 40, and then rises to 145 on 1 in 10, after which the rise is rapid. The figure for the simple rack engine falls from 148 on 1 in 200, to 100 on 1 in 25, and then rises to 178 on 1 in 5. The figure for the tank-engine falls from 164 on 1 in 200, to 124 on 1 in 50, then rises to 155 on 1 in 20, and after that rises rapidly. The tender engine is considerably higher

throughout. The economy of the rack arrangement is thus brought out strongly, on comparatively slight inclines as well as on steep ones. Moreover, no account is here taken of the loss of steam by wheels slipping, which, with adhesion engines, is often large. Another advantage of the rack system is, that the figure is almost constant between 1 in 70 and 1 in 20, thus allowing a large variation in the gradient, according to the nature of the ground. Some further calculations are given as to the amount of traffic which can be conducted over such a railway, which is shown to be very considerable—larger, if the gradients are steep, than on an ordinary railway, because the train load is much greater. In most cases the passenger trains, being light, might be run by adhesion only, so as to allow of their travelling at higher speeds.

The Author finally inquires why, notwithstanding its enormous advantages, this system has not been more widely adopted. The idea that it is only suited for small traffic and low speeds, he has shown to be an error. The weight hauled is much larger than on ordinary railways; and even on steep inclines the time occupied in ascending is less, on account of the much shorter path. That it cannot be worked in frost and snow has been disproved by the Rohrschach and Heiden railway, which works regularly summer and winter, and that without the use of a snow plough, in place of which there are simply a couple of boards screwed on in front of the engine. With regard to safety, 300,000 train-miles have been run on rack railways without a single accident. By fitting one carriage with a wheel gearing with the rack, and actuated by an air brake (at a cost of about £100), the train can be made to stand on any incline, independently of the engine. The Author concludes, therefore, that an exhaustive trial of the system on a main line is eminently desirable.

W. R. B.

Tractional Resistance on Underground Railways.

By A. Evrard.

(Résumé de la Société des Ingenieurs Civils, 1879, p. 250.)

M. Lombard found, in the mines at Graissesac, that the total resistance to traction of the service wagons on the underground lines of railway, varied from $\frac{1}{49}$ to $\frac{1}{63}$ of their weight, or from 36 lbs. to 46 lbs. per ton, according to the system of wheels employed. From M. Bézenet's trials, it was found that the resistance was from $\frac{1}{60}$ to $\frac{1}{68}$, or from 33 lbs. to 37 lbs. per ton.

M. Evrard, in 1877, at Ferfay, found the resistance, on a 2-feet gauge, varying from 23 lbs. to 53 lbs. per ton, according to the type of wheel, mode of lubrication, the age of the wagons, and the degree of accuracy of their construction. In a second series of trials, for wagons in bad order, the resistance averaged 37 lbs. per ton; for wagons in very bad order, 75 lbs. per ton; for whole

trains in average order, from 32 lbs. to 37 lbs. per ton. M. Evrard concludes that, for mine wagon-stock, on ways of 2-feet gauge, well constructed and maintained, the resistance should not exceed 1 in 100, or 22½ lbs. per ton.

D. K. C.

Endless-Chain Mine Railway at Fillols. By C. Helson.

(Annales Industrielles, August 31, 1879, col. 267.)

The iron mines at Fillols, in the Canigou region, Eastern Pyrenees, are situated at a high elevation, from which the minerals are conveyed, by gravitation, in small wagons on a double line of railway, with endless chains. The system extends over a distance of 5 miles in direct length, between the highest point, called Salvé, and the station at Prades. The undulations of the surface are followed, for the most part, though here and there holes are filled up and humps are removed. The railway consists of seven inclined planes, on which two lines of way are laid to a gauge of 21⅔ inches between the centres of the rails. The rails are of Bessemer steel, 14 lbs. per yard, fish-jointed, and laid on transverse sleepers, 30 inches apart. The difference of level at the mine and Prades station amounts to 984 feet. The inclines, direct and reverse, vary from a level to 23 per cent., or nearly 1 in 4; they are connected by short pieces of level line. A directing pulley is placed at the end of each incline, and the system is automatic; as the loaded wagons, descending by gravitation, draw up the empty wagons. Each wagon weighs 500 lbs., and carries a load of ½ ton. The speed is limited to 3·35 miles per hour, at which rate 300,000 tons per year can be transported. The wagons are controlled by means of four brakes with return-pulleys.

The chains consist of ring-links, and weigh from 8 lbs. to 20 lbs. per yard, according to the maximum degree of tension on the different planes. The chain is supported on the wagons, and is attached to each wagon by a fork between the sides of which one of the links enters. The chain is thus entirely supported by the wagons, and is suspended or floated (*chaîne flottante*). The loaded wagons leave the chain at a distance of a few yards before tho pulley, which is raised sufficiently high to lift the chain out of the fork, and arrive quietly on tables. The wagons are pushed on down a slight incline to take the next length of chain, or, if to be removed at this platform, are turned aside and replaced by empty wagons.

The first cost of the floating chain system of transport amounted to £1,276 per mile. The cost for transport varied from ¾*d.* to 2¼*d.* per ton conveyed per mile. The cost for the whole distance, 5 miles, taken at 2¼*d.* per ton per mile, amounts to 1*s.* 3*d.* per ton; whilst formerly the cost for conveyance by oxen amounted to 3*s.* 3*d.* per ton.

D. K. C.

Note on a Remarkable Railway Accident.

By P. Opizzi.

(Atti del Collegio degli Ingegneri ed Architetti in Milano, anno xii., p. 100.)

Signor Opizzi gives particulars, illustrated by a drawing, of a remarkable case of the slipping of the coupled wheels of a locomotive on an ascent of 23 per 1,000, or, according to the usual English notation, of 1 in 43·47.

On December 9th, 1878, a goods train weighing 142 tons was in a tunnel between the stations of Piteccio and Pracchia, on the Apennine railway from Florence to Bologna. The incline through the tunnel is of the gradient above stated; and there is also a curve, of double flexure, of 330 feet radius. The day was stormy, and the tunnel was filled with a dense cloud of steam and gas, caused by the passage of the preceding train, which had ascended the incline, no descending train having intervened between the two ascending trains in question.

The engine, which was built in 1874 by Sigl, of Wiener Neustadt, had eight coupled wheels, and external cylinders. The maximum adherent weight was 52 tons. The diameter of the coupled wheels was 3·84 feet; that of the cylinders 1·74 foot: the length of the stroke was 2 feet. The eccentrics were on the Stephenson principle, and the effective pressure in the boiler was 9 atmospheres.

On starting from Piteccio to the tunnel the train had not attained its designed velocity of 11·16 miles per hour. The rails were damp and slippery, and the slip of the wheels appears to have increased from the moment of entering the tunnel, until the engine failed to advance, when at a distance of a mile from the station at Piteccio. The wheels continued to revolve; and the engine driver, enveloped in a dense cloud of steam, was actually not aware that the course of the train was arrested. The guard was the only person who detected what was taking place. The Paper does not state what measures were then adopted.

It was found that for upwards of 100 yards the rails had been damaged by the action of the wheels; and that near the point where the stoppage occurred, a layer of from ·08 to ·12 inch in thickness had been ground off the top table of the rails, which were of Bessemer steel from the Creusot factory. At the point of stoppage eight depressions were found in the rails, corresponding to the position of the wheels of the locomotive. In the drawing furnished by Signor Mantegazza, engineer-in-chief of maintenance on the Alta Italia railways, the cross section of the rails is such as to represent an ornamental capital T, or a fleur-de-lys with the central point removed. The top table has entirely lost its form, having been bent over on both sides in the form thus indicated. The rail on which the last wheels revolved was raised from its

bearings by about its own depth at the joint. The colour of the metal on these damaged portions of the rails showed that a temperature of red heat, or higher, had been produced by the conversion of the working force of the locomotive into friction. The engine itself was uninjured.

Signor Opizzi calculates, according to the formula of Zeuner, the force which was thus exerted to be 12,760 lbs. The resistance afforded by gravity on the incline was 7,317 lbs. The running resistance of the train, exclusive of the engine, if taken at 10 lbs. per ton, would raise this resistance to 8,217 lbs. Thus it would seem that the resistance opposed by the curve to the eight coupled wheels must have been very great, as the disproportion between the adhesion obtained, and the work to be done, in many instances is otherwise inexplicable.

The view taken by the Author is, that the incident points in the direction of the use of steam of a lower pressure, rendering it possible to use a lighter locomotive; and suggests that, with three cylinders, a constant pressure of 4 atmospheres in the boiler would be sufficient to maintain a force adequate to surmount the incline.

F. R. C.

On the Diurnal Variation of Rainfall Frequency at Calcutta.

By H. F. Blanford, F.G.S., F.Z.S., F.M.S.

(Journal of the Asiatic Society of Bengal, vol. xlviii., p. 41.)

The Author gives a table showing the number of hours in which rain was recorded during twenty-one years (August 1856 to March 1877) at Calcutta, from which the following conclusions may be drawn.

On the average of the year, which is mainly determined by that of the summer monsoon months, the hour at which rain is least frequent is shortly before midnight, and that at which it is most so, from 2 to 3 P.M. The latter accords approximately with the diurnal epoch of maximum temperature, but the former does not accord with its minimum; and, indeed, the frequency of rain at the hour of mean minimum temperature is nearly 40 per cent. greater than at midnight; while at the hour of its maximum it is only twice as great; and it would appear that whilst the greatest heat coincides with a principal maximum of rainfall, the greatest cold coincides with a secondary maximum.

The character of the variation in the rainy months of the summer monsoon does not differ materially from the average of the year; but that of the hot season is very different; and that of the cold season, again, differs from both, and is more uniform than either.

The following table shows the number of rainy hours recorded

during the above-mentioned period, arranged according to the three seasons:—

—	A.M.											
	Midnight to 1.	1 to 2.	2 to 3.	3 to 4.	4 to 5.	5 to 6.	6 to 7.	7 to 8.	8 to 9.	9 to 10.	10 to 11.	11 to Noon.
Rains—June to October . . .	298	327	348	353	364	376	373	373	357	410	458	505
Hot season—March to May . . .	28	29	32	28	21	24	28	25	24	30	29	33
Cold season—November to February	17	18	29	29	29	26	29	28	28	21	34	27

—	P.M.											
	Noon to 13.	13 to 14.	14 to 15.	15 to 16.	16 to 17.	17 to 18.	18 to 19.	19 to 20.	20 to 21.	21 to 22.	22 to 23.	23 to Midnight.
Rains—June to October . . .	543	537	572	477	464	413	397	343	321	261	282	263
Hot season—March to May . . .	36	38	47	66	69	102	90	125	109	81	61	34
Cold season—November to February	24	25	27	28	33	29	25	27	19	19	17	22

The Author suggests the following as a possible explanation of the rainfall variation. The cooling of the atmosphere after 3 P.M., in the first place, checks the production and ascent of vapour, as well as of convective atmospheric currents, and causes a rise of pressure in the lower atmosphere, as a consequence of the sinking and compression of the atmospheric mass. These effects bring about a dispersion of cloud and a fall of rainfall frequency from the absolute maximum to the absolute minimum of the twenty-four hours. About 10 P.M. the compression having reached its maximum, re-expansion sets in, and, in conjunction with continued cooling, raises the relative humidity of the cloud-forming strata, and consequently the tendency to the formation of cloud and rain. When the re-expansion ceases, about 3 or 4 A.M., the loss of heat is still operative in the same direction, though less powerfully; but, after sunrise, the direct effect of the solar heat is to diminish cloud and rainfall, while raising the pressure of the lower atmosphere; and it is not until this increasing pressure has nearly attained its

maximum, and the ascent of vapour has become sufficiently vigorous to prevail over these first effects, that the formation of cloud and rainfall attain their afternoon maximum; this condition coinciding with the highest temperature and the greatest activity of diffusing vapour and convective currents.

Generally the conclusion to be arrived at is, that the conditions promoting and determining precipitation are different at different seasons. In the highly vapour-charged atmosphere of the rainy monsoon, and in a much less degree in the cold season, condensation is most promoted by increasing temperature, and the more active ascent of vapour determined thereby. In a minor degree the opposite action, viz., nocturnal cooling, under certain conditions, produce the same effect, complicated, however, by the internal movements of the atmosphere, due to oscillation of temperature.

In the comparatively dry atmosphere of the hot weather the precipitation is chiefly that of storms, and these are most frequent when the atmosphere, as a whole, is cooling most rapidly.

J. C. I.

The Sewerage of Berlin.

(Bericht der Münchener Commission über die Besichtigung der Canalisations- und Berieselungs-Anlagen in Frankfurt am Main, Berlin, Danzig und Breslau. München, 1879, p. 38.)

The population of Berlin amounts, at the present time, to 1,030,000 inhabitants. Before the introduction of the improved system of sewerage, nearly every house had cesspits, the surplus water in which escaped by means of the street gutters. Only in a few parts of the city were there any old drains. For the purposes of the new drainage scheme, Berlin proper was divided into five divisions, the sewerage of each of which was, by means of a so-called "radial system," rendered wholly independent. These districts are so laid out that the foul water from each of them is conducted by gravitation to a single point, from which it is raised by pumping to irrigation areas. Systems I., II. and III. comprise those portions of the city to the south of the Spree, and systems IV. and V. drain the districts north of the river. For three of these systems, Nos. I., II. and IV., the pumping stations are already completed, as also large portions of the sewerage, though the houses are not yet connected. The remaining systems are in a less forward state.

The steam power, amounting in the aggregate, for the three divisions south of the Spree, to about 500 HP., is furnished partly by Woolf's compound engines, partly by single-cylinder engines. Double-action horizontal force-pumps are employed, which raise the water from the collecting basins. These basins are of masonry, and are furnished with iron cross gratings to intercept solid matters; they have also catch-pits for sand. In the case of heavy floods

which may overpower the pumps, a storm overflow from the sand catch-pits has been provided. The following are the calculations which have been made use of in determining the requisite power, sizes of pumps, sewers, &c. It was assumed that for the 390 hectares (963·74 acres) of surface included in System III., the present population, amounting in all to above 106,000, might increase to 280,000 (from 300 to 800 per hectare), and that a daily consumption of 127 litres (27·9 gallons) of water might be reckoned upon. These figures give a flow of 1·15 litre (0·253 gallon) per hectare (2·47 acres) per second. The maximum rainfall was assumed at 23 millimètres (0·91 inch) per hour, of which, at most, one-third would have to be carried away at once. These figures indicate a theoretical discharge of 21·19 litres (4·66 gallons) per hectare (2·47 acres) per second. It would therefore be necessary to provide for the removal of 1·15 + 21·19 = 22·34 litres per hectare per second; of which volume, however, only the eighth part—in round numbers, say 3 litres per hectare per second—would have to be lifted by the pumps, the remainder being discharged by other outlets into the open water-courses. It would appear, from observations extending over a thousand days, that only on ten occasions was this volume attained, and then only partially over the district. The irrigation areas for the three southern systems lie to the south of the city, and are at such a distance from it that the total length of the rising main, from the pumping station to the boundaries of the meadows, is 12,500 mètres (13,670 yards). In addition to overcoming the loss by friction on this length of pipes, there is a total lift of 21½ mètres (70 feet).

The main sewers are of brickwork, and are egg-shaped in section; the minor sewers are of glazed pipes. The inverts of the former are either cast in blocks of brickwork, or are formed of concrete. In Section III. of the works there are 10,000 lineal mètres (10,936 yards) of main sewers, having a fall of from 1 in 2,500 to 1 in 3,000 and 70,000 lineal mètres (43½ miles) of pipes, varying in diameter from 8 inches to 2 feet. In future only stoneware pipes, of a minimum diameter of 1 foot 7½ inches, are to be employed. In order to diminish the length of the house and street gully connections, there are small side-drains laid along each side of the roads. The depth of the sewers averages from 1·5 mètre (4 feet 11 inches) to 6·5 mètres (21 feet 4 inches); they are for the most part below the level of the subsoil water. No special flushing of the drains takes place, but, if necessary, water can be obtained for the purpose from the hydrants. To provide against the possibility of back-pressure, owing to violent storms, overflows have been arranged, by means of which the superabundant water is passed off into the river. The rainwater downpipes, the street gullies and manholes, are made use of to ventilate the sewers. The manholes are placed from 80 mètres (87·49 yards) to 100 mètres (109·36 yards) apart, and there is one at every cross street. They are furnished with double iron covers, the upper of which is of solid cast iron, the lower one being of perforated wrought iron. The

gullies are placed every 60 mètres (65·61 yards) along the gutters. They are square in plan, 0·65 mètre (2 feet 1 inch) each way. The police regulations compel every house to be connected with the sewers. Fecal matters can only be passed into the sewers by means of waterclosets. For the house drainage stoneware pipes are employed, the general fall for the house connections being 1 in 50. Every pipe leading into the house, which is connected with the main sewers, is carefully trapped. The soil-pipes are carried up to the roofs to serve as ventilators.

The householders are charged 1 per cent. on the rental to cover the cost of connection with the sewers. This produces at the present time an annual revenue of 370,000 marks (£18,500). For the cleansing of the sewers in Section III. a staff of nine men are constantly engaged. The cost of drainage works in Section III., as far as at present executed, is as follows:

	Marks.	£.
1. Building works above ground . . .	392,726·29	(19,636)
2. Constructions below „ . . .	3,404,429·62	(170,221)
3. Rising main and machinery	1,270,817·75	(63,540)
4. Sundries (management)	432,582·95	(21,629)
5. Site for pumping station	366,350·00	(18,317)
	5,866,906·61	(293,345)
Add the cost of work which has still to be executed.	237,000·00	(11,850)
Total.	6,103,906·61	(305,195)

For the acquisition of the land for irrigation, a sum of 1,365,000 marks (£68,250) has been expended, which must be increased by 2,500,000 marks (£125,000), the estimated cost of preparing and adapting it for the purpose.

The works for the water supply of Berlin, formerly in the hands of an English company, have lately been acquired by the city authorities, and the supply to each house is now compulsory. According to the new tariff, a supply of 80 cubic mètres (104·6 cubic yards) quarterly can be obtained for 24 marks (£1 4*s.*); a further quantity of 120 cubic mètres (150·9 cubic yards) is charged for at the rate of 30 pfennige (3*d.*) per cubic mètre: 200 cubic mètres (261·6 cubic yards) a quarter cost therefore 60 marks (£3). The water supply was formerly 40 litres (8·8 gallons) per head.

At the pumping station for Section III., in order to force the sewage through the 12,500 mètres of rising main 0·75 mètre (2 feet 5½ inches) in diameter, there are six engines and six boilers, with pumps capable of lifting 39,000 cubic mètres (51,012 cubic yards, or 8,583,751 gallons), per diem.

The irrigated areas give rise to no nuisance, but the local surface water seems to have been polluted to some extent. The report concludes with a series of extracts from the statement of the Berlin Drainage Works committee, respecting the progress of the sewage works, and the result of the farming operation on the irrigated land during the years 1876–77–78. G. R. R.

The Sewerage of Breslau.

(Bericht der Münchener Commission über die Besichtigung der Canalisations- und Berieselungs-Anlagen in Frankfurt am Maine, Berlin, Danzig und Breslau. München, 1879, p. 58.)

Breslau has, at the present time, a population of about 270,000 persons, and consists of 7,000 inhabited areas (Grundstücken). The old drains are very imperfect, and most houses have, until recently, made use of cesspits; moreover, the cellars were frequently flooded by the subsoil water during the greater part of the year. In laying out the new system of sewers, special effort has been made to bring into use as far as possible the existing street drains, from which all fecal matters have hitherto been excluded. These old drains are mostly rectangular in section, though the more recent ones are of the egg-shaped form, with an average fall of 1 in 1,200. There are four main systems, running parallel to each other in zones round the town, each system being wholly distinct, and at a different level to those adjacent to it. An intercepting sewer has been constructed on the left bank of the river, which picks up the various main sewers of the old "ring systems," brings to one point the different outfalls into the Oder, and removes the place of discharge to a spot much further down the stream. On the right bank of the Oder the existing intercepting sewer has been continued to a new outfall further down the stream.

The new system of sewers comprises the following works: On the west side, 5,375 mètres (5,878 yards) of brick sewers, and 13,275 mètres (14,518 yards) of pipe-drains; on the south side, 5,780 mètres (6,321 yards) of brick sewers, and 3,390 mètres (3,707·4 yards) of pipe-drains; on the eastern division, 5,370 mètres (5,872·8 yards) of pipe-drains; for the inner town, 1,550 mètres (1695·12 yards) of pipe-drains, and for the northern section, 6,030 mètres (6,594·6 yards) of brick sewers, and 11,330 mètres (12,390·8 yards) of pipe-drains.

For the determination of the volume of sewage to be removed on the left bank of the Oder, the following factors were employed: For the surface, consisting of 1,670 hectares (4,126·6 acres), a rainfall equivalent to 5·23 centimètres (2·06 inches) per twenty-four hours was assumed. For the area on the right bank, comprising 705·3 hectares (1,742·8 acres), a rainfall of 2·615 centimètres (1·102 inch) in twenty-four hours was assumed, in consequence of the land being much less built over. In addition to these totals, the daily water-supply, amounting to 150 litres (33 gallons) per head, had also to be taken into account.

The brick sewers have inverts of granite; they are constructed with hydraulic mortar, and are not coated with cement stucco. They are egg-shaped in section, and vary in size from 0·4 × 0·6 mètre (1 foot 3¾ inches × 1 foot 11⅝ inches), to 2·0 × 3·0 mètres (6 feet 6¾ inches × 9 feet 10⅛ inches). They are made use of

wherever stoneware pipes 0·47 mètre (1 foot 6½ inches) in diameter are insufficient to carry away the water.

The principal sewers have a minimum fall of 1 in 1,800, the minor side drains 1 in 500, and the pipe-drains 1 in 300. Curves of not less than 11 mètres (12·03 yards) radius are employed for the brick sewers; no curves are permitted in pipe-drains. Open gutters are carried along each side of the principal streets, with gullies varying from 50 mètres (54·68 yards) to 100 mètres (109·36 yards) apart. The gullies are constructed in cement concrete, and are all trapped. Provisions are made at various points for flushing the sewers—an operation which takes place weekly; five men and a foreman are specially employed in this work on each bank of the river. Flushing boards are made use of to obtain a head of water. For the ventilation of the sewers: 1. All the manholes are provided with perforated covers: no charcoal trays are used. 2. The down-pipes for rainwater are untrapped. 3. The soil-pipes to the closets are continued to points above the roofs of the houses. The soil pipes vary in diameter from 10·56 centimètres (4·13 inches) to 15·69 centimètres (6·18 inches); the ventilating pipes, continued upwards from the closet to the roof, must have a minimum diameter of 5·23 centimètres (2·06 inches).

The sewage will be pumped from the present outfalls, collected to one point, to the irrigation-areas in a rising main 0·9 mètre (2 feet 11½ inches) in diameter, and 1,400 mètres (1,531·08 yards) in length. The pumps will be capable of lifting 0·5 cubic mètre (110 gallons) per second under ordinary conditions, or 1 cubic mètre (220 gallons) per second as a maximum quantity, to a height of 8 mètres (26 feet 3 inches). The mode of utilising the sewage on the irrigation-areas is described.

The cost of the entire work is estimated at 5,000,000 marks (£250,000), including the cost of the principal pumping station, the smaller ditto at the sewage farm, and the carriers. But this total is exclusive of the cost of the land for irrigation, and 200,000 marks (£10,000) for the drainage of the southern portion of the town. The annual cost of maintenance, exclusive of the farm, is set down at 55,000 marks (£2,750).

G. R. R.

New Ideas on Hydraulics, chiefly relating to Pipes, Canals, and Rivers, with a Theory of the Estimation of Molecular Resistances. By P. Boileau.

(Mémoires de la Société Nationale des Sciences Naturelles et Mathématiques de Cherbourg, tome xxi., pp. 5–182.)

The general motion in a stream is first discussed, and the law announced that where filaments have different velocities, the slower moving deviate towards the quicker. Other external motions, such as eddies and induced currents, are then discussed. The periodicity

of the motion of translation in streams is pointed out. In a stream moving in contact with solid surfaces, there is a region comparatively limited in extent, near the surfaces, where the internal movements are violent. This is termed the troubled zone. The difference of the law of flow in small and large pipes is ascribed to the large proportion of the section occupied by the troubled zone when the pipe is very small.

The Author then shows that a stream in uniform régime may be divided into layers, bounded by surfaces traced out by lines parallel to direction of translatory motion, which have curves of equal velocity for directrices. Each layer consists of molecules having the same mean velocity of translation. The resistance to the motion of the stream is shown to be due to the components parallel to the stream of the reactions due to the roughnesses of the sides; to the shearing of the fluid contained in capillary pores of the surface on which the fluid moves; and to the internal movements in the stream. After some discussion of a general theory of these resistances, the Author proceeds to examine the law of distribution of velocities in the section of a stream. He first points out that, in many experiments hitherto made, the necessary conditions for obtaining true results have not been fulfilled. Experiments of his own in 1845 showed that the filament of greatest velocity (the principal filament) divides the vertical longitudinal section of the stream into two parts, in which the distribution of velocity is not exactly the same. Below the principal filament a formula of the form $v = A - B z^2$, where z is the depth from surface, exactly expressed the law of variation of velocity. Results selected from the Mississippi experiments, and from those of Bazin, confirm the law for extremely different cases. A general expression is then found, applicable to all streams, for the position of the principal filament. In vertical sections other than that passing through the principal filament, the filament of greatest velocity is lower than the principal filament. An expression is then found for the distribution of velocities in a horizontal section, and this is compared with the selected experiments.

The flow of water in pipes is then investigated, some of Darcy's experiments being used to test the results. Taking from Darcy the mean velocities U, and the maximum velocities V, the remarkable result is obtained that

$$\gamma = \frac{V - U}{\sqrt{i}}$$

is constant for each pipe, i being the loss of fall per unit length. Darcy's results being insufficient for the purely empirical determination of the law of distribution of velocity in a pipe, the Author seeks a rational basis for such a law. This leads to the adoption of the expression

$$\gamma = a + b\, R^{\frac{5}{2}},$$

where a and b are constants depending on the roughness of the

sides of the pipe. This enables him to obtain the following law for the distribution of velocity:

$$V - v = \frac{7}{4}\gamma\sqrt{i}\left(\frac{y}{R}\right)^{\frac{3}{2}},$$

where V is the maximum velocity, R the radius, and v the velocity at radius y. From this, formulæ for the mean velocity, velocity in contact with sides and discharge are deduced. It is one consequence of the formula above, that the velocity at a radius 0·6887 R is the mean velocity. Darcy had placed the mean velocity at almost exactly the same point.

The law of distribution of velocity in pipes is then compared with that independently found for streams. It is shown that the former is a particular case of the latter.

The external resistances and internal actions which give rise to the variation of velocity in a stream are then examined, and the defectiveness of the old notions of friction on surfaces, on which Prony's formula is based, is pointed out. For the intensity ϕ of the resistance to the relative motion of two consecutive layers, at radius y, in a pipe of radius R, the value obtained by the Author is,

$$\phi = \frac{32}{441}\,\delta\,\frac{R^3}{\gamma^2}\left(\frac{d\,v}{d\,y}\right)^2,$$

δ being the density of the liquid. This expression differs in form from those proposed by Navier, Darcy, Boussinesq, and other hydraulicians, not only as to the influence of the diameter, but also in the variable factor for the same pipe. For canals and rivers the corresponding expression is

$$\phi = \frac{1}{4}\,\delta\,\frac{H^4}{\mu^2}\,\frac{r_1}{z^2}\left(\frac{d\,v}{d\,z}\right)^2,$$

where r_1 is hydraulic mean radius of the liquid cylinder considered, z its depth from the surface, H the whole depth of stream, and μ a constant depending on the roughness and form of channel.

It remains next to estimate the intermolecular work which gives rise to the resistance to relative motion of the layers. In streams the molecules are displaced transversely from slower to quicker parts, their place being taken by other molecules coming from above. The ratio of the intermolecular work to the whole work of gravity on the stream is found to be

$$\frac{\zeta}{i} = 1 - \frac{w}{U},$$

where ζ is the fall expended in overcoming intermolecular resistances, i the whole fall lost; w is the velocity in contact with the sides, and U the mean velocity of the stream.

Deducting the intermolecular work, the remainder of the resistance to the motion of the stream is due to the action of the surfaces bounding it; and this alone is, strictly speaking, friction. The amount of the intermolecular and frictional resistances in Darcy's experiments on smooth and incrusted pipes is then calculated and discussed.

W. C. U.

On Hydrometry. Prof. v. Wagner.

(Deutsche Bauzeitung, 1879, p. 231.)

In measuring streams there are twelve to fifteen sources of error very prejudicial to the work of the hydraulician. The most important errors arise in the determination of the coefficients of the measuring instruments. Woltmann's current meter is the most generally adopted instrument. All lubricants should first be absolutely removed. Next a long distance (100 mètres) should be chosen, in which to make observations by moving the instrument in still water. Lastly, the means of moving it requires consideration. Usually it is merely fixed on a rod held in the hand, a very rough and imperfect way of treating it. A light movable platform is sometimes employed for the observer and instrument, rolling on iron rails. If the canal, over which the platform is placed, is narrow (1 to 3 mètres wide), the resistance of the sides alters the relation of the number of revolutions and velocity. If the canal is broad (say 5 mètres), the platform must be heavy to prevent oscillations. A boat moved in the still water of a reservoir is a better means of transport for the instrument. Grebenau, in determining the coefficients for the instrument used at Germersheim, caused the boat to move by the aid of a man standing in it and pulling on a rope. At higher velocities it was impossible to avoid considerable variations of speed. To reduce the error he made three hundred observations, which involved great labour.

To determine the coefficients of a new current meter, the Author used two grooved wheels on each side of the reservoir, with an endless rope attached to a double boat. The wheels had 12 feet circumference, and little pegs on the circumference struck springs on the frame. Two men rotated the wheels, in such a way that the striking of the springs was simultaneous with the movements of the second-hand of a watch. By using more or fewer pegs the velocity was varied, and the motion in all cases was regular and uniform.

W. C. U.

Hydrometric Observations in the Basin of the Seine.

By G. LEMOINE.[1]

(Annuaire de la Société Metéorologique de France, vol. xxvii., 1879.)

Regular hydrometric observations in the basin of the Seine have been made since 1854, the principal results having been published in 1872 by M. Belgrand, who originally established them, and continued to direct them until his death in 1878, since which the French Government has charged the École des Ponts et Chaussées with the direction of the work.

The year 1877 was wet—somewhat similar to 1876—when the Seine experienced one of the most remarkable floods of the century. Dividing it for convenience of observation into two parts, namely, from the 1st of November, 1876, to the 30th of April, 1877, and from the 1st of May to the 31st of October, 1877, it is noticeable—

1. That the winter of 1876–77 was extremely mild, especially during the months of December and January. The rainfall was above the average, owing to heavy rains in February and March, which gave rise to two considerable floods of the Seine. Heavy rains also fell in April, but their effect on the flow of the rivers was modified by the increased evaporation due to the higher temperature.

2. The warm season of 1877 showed great irregularities of temperature, but the rainfall was near the average, and with the exception of floods of the Oise during September, the flow of the rivers was neither exceptionally high nor exceptionally low.

3. The cold season of 1877–78 was not unlike that of 1876–77, being mild and wet; but the excess of rain was less than that of the preceding winter, and was so distributed that the floods, though frequent, were of slight elevation.

The three successive winters between 1875 and 1878 were marked by wet weather, especially the winter of 1876.

The character of the rainfall in the basin of the Seine is now well understood, the number of observations being ample for the purpose; but the Author considers that efforts should be made to secure greater exactness, as the differences resulting from defective apparatus or negligence on the part of the observers are often as great as those from which it is sought to deduce general laws. A comparison of the observations taken at different stations shows that the quantity of rain falling at any point depends in a great measure upon its altitude, and upon its location, or distance from the sea.

The Morvan, a district situated at the junction of the Departments of Nièvre, Côte d'Or, Yonne, and Saône-et-Loire, is the most elevated portion of the basin of the Seine; its summit, the Haut

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[1] *Vide* Minutes of Proceedings Inst. C.E., vols. xlv., p. 308; xlvi., p. 299; and l., p. 221.

Folin, is 2,960 feet above the level of the sea. An average of five stations in this district, ranging from the Haut Folin to Les Settons near the source of the Cure, with an altitude of 1,955 feet, shows a rainfall, during 1877, of 76·3 inches, and an altitude of 2,360 feet.

Leaving the summit, but still keeping in the upper portion of the basin, an average of ten stations in the basins of the Yonne, the Seine, the Marne, and the Oise, ranging in altitude from 1,828 feet at Château Chinon, to 614 feet at Bar-le-Duc, gives a rainfall of 44 inches, and an altitude of 1,210 feet.

An average of eight stations still lower in the basin, including Paris and its neighbourhood, gives a rainfall of 27·2 inches, and an altitude of 206 feet. This is the district of minimum rainfall, for on approaching the sea an average of six stations, including Rouen, gives a rainfall of 35·7 inches, and an altitude of 250 feet.

Some inequalities which occur regularly between the rainfall observed at different stations are due to topographical conditions, and particularly to the extent to which the stations are exposed to rainy winds. For instance, at Les Settons in the Morvan, 81·61 inches of rain fell, while at Saulieu, situated almost at the same altitude, only 32·32 inches fell; this great difference was due to the westerly and south-westerly winds discharging the greater part of their moisture upon the upper part of the Morvan before reaching Saulieu.

The rainfall in different parts of the basin is very unequally divided between the two seasons of the year, and this fact may be shown to have an important influence upon the régime of the river. At Paris and in its neighbourhood the summer rainfall is greatly in excess of that of the winter, but in the more elevated portions of the basin this law of distribution does not hold good, the rainfall in winter being equal to or even exceeding that of the summer; and as the elevated portions of the basin situated on impermeable strata are the real sources of the floods of the Seine, which usually occur in winter, the fact that in these portions the rainfall in winter is abundant has an important bearing upon the régime of the river. The observations also show that the upper portions of the basins of the Yonne and Marne exercise a much greater influence upon the floods of the Seine than would have been supposed prior to their establishment. The mean rainfall for the year was 32·32 inches, the average for the last sixteen years being 25·83 inches, and the excess was most sensible in the middle and lower portions of the basin.

M. Belgrand has calculated that the area of the basin of the Seine may be divided into 7,505 square miles lying upon impermeable strata, and 22,865 square miles upon permeable strata, the whole area of the basin being 30,370 square miles. The observations of 1877, like those of preceding years, prove the connection between the régime of rivers and the geological character of the strata in which they have their origin; those rising in impermeable strata being torrents, while those flowing from permeable

strata are of a more tranquil character, and more slowly affected by heavy rains. Down to Montereau the Seine is a tranquil stream; below this point its flow is influenced by the torrential waters of the Yonne, but since the basin of the Yonne is situated chiefly upon impermeable strata, its floods always pass down before those of the Upper Seine. From these facts it follows that to be able to foretell the floods of the Seine, it is necessary to observe only the torrential streams, as the waters from the permeable strata arrive later, and do not affect the maximum height reached by the flood, but only its duration.

The risings of the Seine at Paris have been regularly foretold since 1854, the maximum height being usually known three days beforehand; and in 1877 the five principal warnings issued were, with one exception, within a few inches of the heights actually reached by the river. The maximum flood of the cold season of 1877–78 only reached a height of 11·81 feet upon the gauge of the Pont d'Austerlitz at Paris, while that of March 1876, which ranks as the third flood of the century, attained a height of 21·95 feet at that point, and that of February 1877, 14·1 feet. The zero of the gauge being approximately the summer level of the river, the above figures represent the vertical rise of the floods at Paris.

The observations referred to in this article consist of diagrams showing graphically the height of the water, its clearness or turbidity, and its temperature, daily, from the 1st of May, 1877, to the 30th of April, 1878, at various points on the Seine and its tributaries; and the daily rainfall from the 1st of January to the 31st of December, 1877, at more than one hundred stations.

A. H. S.

On the operations for obtaining the Discharges of the large Rivers in Upper Assam, during the season 1877–78.

By Lieut. H. J. Harman, R.E.

(Journal of the Asiatic Society of Bengal, vol. xlviii., p. 4.)

One of the survey operations during the field season of 1877–78, was to explore as much as possible of the region between the Subansiri and the Dihang rivers, with a view to ascertaining which of these two affluents of the Brahmaputra river had the best claim to be considered the recipient of the Sanpo river of Thibet.

The method of procedure in measuring the Subansiri and the other river was as follows.

A gauge post was planted in the bed of the stream to note the

variation in level of the water during the operations. Four parallel lines were laid out across the river at a perpendicular distance apart of 758 feet, the shore portions of the lines being marked by flags.

A base line along the bank and up-stream from the first parallel line was measured on each side of the river, and at the up-stream ends of these base lines, on a plane table, a chart was made on the scale of 70 feet to an inch, showing the lines of flags and the margins of the river. The section was obtained in the following manner:

A small "dug-out" was anchored above the highest parallel line at the required distance from shore, and the cable eased off until the observer in the boat was exactly on the upper parallel line. A signal was made to an assistant stationed with the plane table at either bank, who at once cut in the position of the observer in the boat on the upper line. Soundings were then taken, and the boat let down to the second parallel line or upper line of the "Run." The position of the observer in the boat was again cut in and soundings taken; and so on for the remaining two lines.

The instruments for measuring velocities were disks of wood 3 inches in diameter and ½ inch thick, marked by a little mass of cotton wool thrown over a peg standing upright in the centre of the disk. Also tin tubes of 1 inch diameter, closed at one end, varying in length from 2½ to 10 feet, containing enough water to sink the tubes, so that only 3 or 4 inches remained above water. In the mouth of the tube was a cork and cotton wool for a marker.

To measure the velocity, the boat was moored on the upper parallel line, the floats dropped into the water, and the general line of direction taken by them observed with a prismatic compass; on one bank were two observers, each furnished with a good binocular, stationed at the second and third lines. A recorder with a large chronometer (Dent's), beating half seconds, was placed half way between the two observers. When the observer saw a float cross the second line he cried "past," and the recorder at 0 noted the time in his book; when the second observer saw the float cross the third line, he likewise gave the time to the recorder. The interval between the two noted times gives the time taken by the float to pass over the "Run."

(*a.*) The bottoms of all the rivers measured were heavy sand, excepting a short stretch of big pebbles in the bed of the combined Dihang and Dibang rivers.

Professor Rankine assumes that the mean velocity on a vertical line, is to the greatest velocity on the same line, as 3 to 4 for slow rivers and 4 to 5 in rapid streams.

The velocity of a rod extending to nearly the bed of the stream is approximately the mean velocity of the water in the vertical plane traversed by the rod. In assigning a mean velocity for

computation to the several portions of the sections of the rivers, all the above facts were kept in view.

(*b.*) The arithmetical mean of the times noted at a station of the passages of a certain floating instrument, was taken as the mean time of passage of that instrument. Having obtained at a station the mean time of passage of each kind of instrument, and having regard to the number and quality of the observations, a value was assumed as representing the mean time of passage of the water at that station.

For the adjacent station, a mean time of passage was obtained in a similar manner. Then, for the whole included section, a value was assumed as representing the mean time of passage, and this value was employed in the computation.

In cases where the velocities between the two lines were very different, and defined by a margin line of the current, the section was subdivided into two parts, each dealt with by itself.

(*c.*) The flood discharges are merely probable values obtained from the Revenue Survey large scale maps of the river, corrected for changes observed when computing the discharges.

(*d.*) Some of the rivers measured were about the mean low level of the dry season. To obtain the discharge of the river at its mean low level of the dry season, the area of each portion of the section, due to rise, was computed and subtracted from the observed area of that portion; then to the diminished area of the portion a mean velocity was given which was less than the observed mean velocity of the portion.

(*e.*) The sum of the discharges of the rivers forming the Brahmaputra river should equal the discharge of the Brahmaputra itself. The work done approximates this test sufficiently to allow of the stated discharges being considered good for geographical purposes.

From the Synopsis Table attached, it will be seen how closely the sum of the volumes observed for the two great streams which form the Brahmaputra river, agree with the observed volume of the river at Dibrugarh.

The river at Dibrugarh should be of greater volume than the combined Dihang and Sadiya streams, because of the Lali channel of the Dihang, which joins just below the place where the section of the Dihang and Dibang was taken.

During the cold season, and at the time of observations it was a small and fordable stream 100 yards wide, but during floods the channel brings down a large volume of water.

During the floods a considerable volume of water passes down the Buri Luti, the mouth of which is on the north bank, and between Dibrugarh and the mouth of the Dihang river.

The Buri Luti falls into the Brahmaputra, near the mouth of the Dihang river, south of Dibrugarh.

SYNOPSIS TABLE. RESU

Name of River.	Discharge in cubic feet per second at mean Low Level of the Year.	Sectional area in superficial feet at mean Low Level of the Year.	Mean Velocity in feet per second at mean Low Level of the Year.	Discharge at ordinary High Floods.	Sectional area at ordinary High Floods.	Mean Velocity in feet per second at ordinary High Floods.	Discharge at extreme
Dihang + Dibang river .	82,652 (d)	18,883 (d)	4·3 (d)	485,000 (d)	84,000 (d)	5·7 (d)	56 ((18 fe
Brahmaputra river, above Sadiya, and below mouth of the Tengapáni river	33,832 (d)	8,228 (d)	4·1 (d)	293,000 (d) (16 ft. rise)	53,017 (d) (16 ft. rise)	5·5 (d)	33 ((18 f
Total .	116,484	27,111	4·2 about	778,000	137,017	5·6 about	89
Brahmaputra river at Dibrugarh. .	116,115 (d)	24,474 (o)	4·6 (o)	830,000 (d)	164,000	5·0	1,10
Difference	−369	..	..	+52,000	..	..	+17
Dibang river below mouth of Senseri river . .	27,202 (d)	6,375 (d)	4·2 (d)	122,483 (d)	23,692 (d)	5·2 (d)	14 (16 fe
Senseri river .	1,200 (e)	..	..	12,000 (e)	..	..	1 (
Dihang river (less the Lalisuti) . .	55,400 (d)	..	..	362,517 (d)	..	..	42 (
Tengapáni + Noa Dihing	3,000 (d)	900 (d)	3·3 (d)	53,000 (d) (15 ft. rise)	10,400 (d) (15 ft. rise)	5·1 (d)	6 (
Tengapáni river . .	2,500 (e)	..	..	22,000 (e)	..	..	36 (
Noa Dihing river . .	500 (e)	..	..	..	..	..	..
Digáru river .	5,000 (e)	..	..	60,000 (e)	..	..	75, (d)
Subansiri river	16,945 (o)	9,637 (o)	1·7 (o)	170,000	35,700	4·7	269,
Brahmaputra at the Bramakund. .	25,000 (d)	..	..	180,000 (d) (16 ft. rise)	..	..	200, (d) (18 feet

NOTE.—(o) means observed value; (d) deduced value by comp

DISCHARGE MEASUREMENTS.

Sectional area at extreme high Floods.	Mean Velocity in feet per second at extreme High Floods.	Measured discharge of River when it was 3 feet above mean Low Level of the Year.	Measured sectional area when River was 3 feet above mean Low Level of the Year.	Observed mean Velocity when River was 3 feet above mean Low Level of the Year.	Date of Measurement.	Site of Section.	No. of Soundings taken for Section.	No. of stations at which observations were made for velocity.	No. of recorded passages of floating instruments.
96,000 (e) (18 feet rise)	5·8 (e) (18 ft. rise)	110,011 (o)	25,105 (o)	4·4 (o)	1878. March 24 to 27	1 mile S. of Dibang river, and 1 mile above junction with Brahmaputra.	59	12	170
59,000 (e) (18 feet rise)	5·5 (e)	66,251 (o)	16,396 (e)	4·0 (o)	April 3 to 6	9 miles above Sadiya, and ½ mile below the mouth of the Tengapani river.	16	14	165
157,000	5·7 about	176,262	41,501	4·2 about					
208,000 (e)	5·3 (e)	170,915	38,500	4·4	March 16, 17, 18	At a place due N. of, and 3 miles from Dibrugarh.	120	14	255
..	..	−5347	..	..	..				
27,700 (18 feet)	5·2	47,383 (o) At 5 feet above mean low level of the year.	10,992 (o) At 5 feet above mean low level of the year.	4·3 (o) At 5 feet above mean low level of the year.	March 27	¼ mile below the mouth of the Senseri river.	37	9	116
..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..
800)	5·1 (e)	6,807 (o)	2,203 (o)	3·1 (o)	April 6	200 yards below junction of Tengapáni river with Noa Dihing river	18	2	19
	..	2,500 (e)	..	..	..	..	..	..	..
	..	4,307 (e)	..	..	..	..	..	..	..
	..	..	..	..	..	..	..	..	..
	4·9	..	..	..	..	..	..	..	..
	..	..	..	..	Feb. 25 to 28	Pathalipam village, 3 miles W. of Gogah Muk.	90	21	510
							385	72	1,235

d value.

Completion of the Inland Navigations of France.

(Report of the Commission named by the Chamber of Deputies.)

(Annales Industrielles, 3 and 10 August, 1879, col. 151, 178.)

On the 4th of November, 1878, the Minister of Public Works deposited at the bureau of the Chamber of Deputies a draft Bill, providing for the systematising and improving the internal navigation of France; a measure which has been demanded by public opinion as the necessary complement to the completion of the railway system in that country.

The Commission states that it is impossible to fulfil the requirements of commerce and industry without the service both of railways and of canals. The latter, as incontestably the cheaper, are requisite for certain wants. Heavy articles of merchandise, of low price, such as coal, minerals, building materials, lime, manure, &c., furnish the great bulk of transport, and cheapness is the most essential requisite for their distribution. The delay of a week or a fortnight in the delivery of these articles is a matter of little importance; while the difference of freight for long distances, between the lowest rate at which a railway can carry and that which is attainable on a canal, is equal to half the price of the goods. The facilitation of water carriage will thus equalise the cost of these articles throughout the country.

Thus coal, the Commission states, cannot be carried on railways, even for long distances, at a less cost than from 0·54*d.* to 0·62*d.* per ton per mile; but can be transported by canal at less than half the lowest of those rates; that is to say, for 0·22*d.* per ton per mile.

The development of canals is so much the more necessary, from the fact that the carrying power of the railways is already, in many cases, taxed to the full. Thus, in the north of France the traffic is nearly equally divided between the railways and the canals. The great service which the latter can render to the country is thus to be measured by the saving of from 0·34*d.* to 0·40*d.* per ton per mile on the immense tonnage transportable by canal.

For these reasons, continues the Report, the draft Bill of the Minister of Public Works has been thoroughly approved by the public opinion of France. The bill provides for the classification and the improvement of the inland water-ways. The latter work applies to the whole existing network of navigable water, which covers a length of 7,400 miles. The estimate for the works required amounted to £33,200,000, a sum which subsequent additions raised to £40,000,000. Although the above estimates are only provisional, the amount is regarded by the Commission as not affording any ground for disquiet, as the annual outlay will be regulated by the resources at the disposal of the Minister of Public Works.

The internal water-ways of France are divided by this Bill into two classes; principal and those of secondary lines. The former, being of public interest, will be administered by the State, and cannot be conceded to private persons. The latter may be conceded for a limited period, and without any subvention from the State, to companies or to individuals. The Commission approves of this arrangement; it further recommends the suppression of the tolls now exacted by the State on the inland waters, the amount of which, in the budget for 1880, is £166,920. The second clause of the Bill gives the minimum depths of water-way in the canals, and the minimum dimensions of locks, as follows: Least depth of water (which is measured on the sill of the lock), 6·56 feet; width of lock gates, 17 feet; clear length within lock, 116·2 feet. In certain cases larger dimensions will be required. Thus, in the works for improving the Lower Seine, the minimum depth to be attained between Paris and Rouen is fixed at 10 feet 6 inches.

The project submitted to the Chamber comprises the classification of 4,340 miles of canals and rivers as principal. The completion of this part of the network involves the outlay of £11,680,000 on the improvement of existing water-ways, and that of £16,800,000 on the construction of new ones; making a total of £28,480,000. This sum, however, does not include the cost of the lines of canal which are to be purchased by the State. These are: —

1. The lateral canal of the Garonne, 171 miles; 2. The canal of the South, 131 miles; 3. The Beaucaire and Radelle canal, 36½ miles; 4. The canal from Dunkirk to Furnes, 8½ miles; 5. The Lower Scarpe, 22½ miles; 6. The Sambre and Oise canal, 75½ miles: or a total of 445 English miles.

The Commission calls attention to the great importance of the purchase of these lines by the State; more particularly of those forming part of the great line of communication between the Atlantic and the Mediterranean, which at present, in consequence of an unjustifiable error on the part of the Government, is in the hands of the Southern railway company. A list of the lines classed as principal is given, including those already constructed and the proposed additions.

For the secondary lines the approximate sum of £8,640,000 is estimated as necessary, of which £6,000,000 is apportioned to improvement of existing water-ways, and £2,640,000 to the construction of new lines. The whole scheme comprises the improvement of forty-two rivers, and of thirty-one canals, and the formation of ten principal and of ten secondary lines of junction. The map which accompanies the project shows by distinct colours the principal and secondary lines, and whether they are existing, are in course of construction, or are projected.

F. R. C.

The Suez Canal.

(Extracts from Report of M. de Lesseps to the Shareholders, May 28th, 1879.)

Since the opening of the canal the traffic and navigation receipts have been as follows:—

—	Number of Ships.	Tonnage.	Receipts.
			£
1870	486	435,911	206,373 [1]
1871	765	761,467	359,749
1872	1,082	1,439,169	656,304
1873	1,173	2,085,072	915,893
1874	1,264	2,423,672	994,376
1875	1,494	2,940,708	1,155,453
1876	1,457	3,072,107	1,200,000
1877	1,663	3,418,949	1,319,974
1878	1,593	3,291,535	1,243,930

During the year 1878 the mean tonnage per ship was 2,066 tons, and the average tolls about 7*s.* 6*d.* per ton, or £780 per ship. The above 1,593 ships included 1,089 ordinary steamers, 282 mail steamers, 75 transports, 4 ironclads, 7 yachts, and 25 sailing vessels. The passengers consisted of 58,274 soldiers, 26,170 civilians, and 11,919 pilgrims. It is worthy of note that, in May 1878, a fleet, consisting of 10 steamers and 16 sailing ships, passed through the canal, with 8,412 British troops bound for Malta, and that in August and September the same troops returned to India in 14 steamers, 1 transport, and 6 sailing ships.

The mean time, inclusive of stoppages, occupied in passing through the canal in 1878 was 40 hours 10 minutes. Deducting stoppages, this would correspond to a mean speed of about 5¾ miles per hour when under way.

A minimum depth of 26 feet 3 inches, for a width of about 72 feet, is maintained by dredging. In the past year four vessels drawing 24 feet 6 inches made the transit. The widest vessel which has hitherto passed is H.M.S. "Shannon," of 54 feet beam.

To maintain the required depth of water in the ports and canal during the year, no less than 1,660,000 cubic yards of material had to be removed by dredging or otherwise.[2] Of this quantity, 580,000 cubic yards pertained to the Port Said entrance, 40,000 cubic yards to the Port Said basins, 990,000 cubic yards to the canal and passing places, and 50,000 cubic yards to the banks in the Ismalieh section above water level.

M. de Lesseps remarks that, amongst the numerous objections urged against the Suez canal, there remained but one which had not been completely refuted. This was the objection founded on

[1] Calculated on the basis of 25 francs = £1 sterling.

[2] This quantity is about 1⅗ per cent. of the total excavation effected in making the canal.

the alleged impossibility of making a satisfactory and permanent port on an exposed coast near the mouth of a great silt-bearing river, and in a region where the prevailing winds blow towards the entrance of the port and canal.

It was hoped and believed that the company's large sea-going dredger would be able to deal with the sand and silt deposited after westerly gales in front of and around the pier heads at Port Said, and that the formation of a bar, and the consequent necessity for lengthening a jetty already nearly 2 miles long (3,000 mètres), would thus be prevented. This anticipation has been happily realised; and for the following, amongst other reasons, it is claimed that Port Said harbour may now be considered to be in a permanent and normal condition of stability.

Little or no Nile deposit is found on the shallow bottom of the Pelusian gulf, and generally the disturbances caused by the construction of the jetties have affected only a portion of the coast, and that but slightly. Even close to the port, the state of equilibrium has been re-established and maintained with ease for some years past.

The deposits of sand necessitating the annual dredging occur principally on the north and north-east of the large jetty, within limits not extending more than from 900 to 1,100 yards from the foot. Beyond these limits the deposits, being very light, are removed from year to year by the action of the sea alone. The same may be said of the deposits which tend to form on the west of the jetty, at a distance of from 500 to 1,100 yards from the foot, in the eddy formed by the meeting of the current, reflected by the jetty and the main littoral current.

This localisation of the deposits being well ascertained by soundings and observations of currents, the remedy was both obvious and simple, since it consisted merely in providing sufficient dredging plant to remove, in the fine weather, the materials deposited during the winter. This has been done since 1874, and with perfect success, as the charts demonstrate.

Since the advancement of the coast line west of the jetties has now stopped, there is nothing, in M. de Lesseps' opinion, likely to occur to affect the permanency of the channel and port.

During 1878 the repairs to the western jetty necessitated the placing of but forty new blocks, and the resetting of twenty-seven others, notwithstanding the severe storms of February and December. The general improvements effected during the year included the enlargement of some of the passing places, the easing of curves, and the pitching of portions of the banks with about 28,000 tons of stone.

From an examination of the accounts presented with M. de Lesseps' report, it would appear that the cost of the Suez canal and associated works, including the offices in Egypt and Paris, was, on December 31st, 1878, estimated at slightly under 20 millions sterling (496,144,432 francs). The share capital and loans are, of course, considerably less than this amount, by reason of the large

indemnities paid by the Viceroy under the late Emperor Napoleon's award of July 1864, and on other occasions.

During the year 1878, the administrative expenses in Egypt and France amounted, in round figures, to £47,000; the estate charges to £17,000, the transit service to £64,000, the maintenance to £75,000, and the whole expenses to about £211,000. The gross receipts from all sources being £1,300,000 (32,496,335 francs), there remained, after payment of expenses and preference charges, &c., a sum of about £145,000 to be distributed, in the proportions of 71 per cent. to the shareholders; 15 per cent. to the Egyptian Government; 10 per cent. to the "founders," and 4 per cent. to the company's servants.

B. B.

[NOTE.—Adopting the more familiar form of the railway returns of this country, it may be stated that, in round figures, the Suez Canal and works cost £200,000 per mile, and earn a gross return of £250 per mile per week, with working expenses of 16¼ per cent. Comparing these results with corresponding returns for, say, the North London railway, it appears that the canal cost 37 per cent. less per mile, but on the other hand, earns 62 per cent. less gross receipts, and 42 per cent. less net receipts than the railway.—B. B.]

Notes on the Consolidation and Durability of the South Pass Jetties, Mississippi river, with a Description of the Concrete Blocks and other Constructions of the last Year.

By M. E. SCHMIDT.

(Transactions of the American Society of Civil Engineers, 1879, p. 189.)

Since the Paper of Mr. E. L. Corthell,[1] the resident engineer, in which he says the works are still incomplete, rapid progress has been made in the construction of the jetties and improvement of the channel.[2] The east jetty is 11,800 feet long, and the west jetty, commencing at a point 4,000 feet below the former, extends to the same distance seawards, and thus has a length of 7,800 feet. The jetties are 1,000 feet apart, and are parallel to each other, the upper end of the western being connected with the shore by a transverse dam 600 feet in length. Both jetties, with the exception of the lowest 1,000 feet, are raised permanently to the level of average flood tide; the top of the mattress work is 20 feet wide, covered with a layer of stone 1 foot in thickness; they terminate 2¾ miles seaward of the pre-existing eastern shore line. The mean velocity of the river currents during flood stages is three miles

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. lv., p. 367.

[2] The jetties have since been completed. *Vide* an article by Mr. Corthell in "Scribner's Monthly" for November, 1879, and "Engineering" November 7, 1879.

per hour, decreasing to three-quarters of a mile per hour during low water.

The east jetty for 8,000 feet, and the west jetty for 9,000 feet, seaward, are to be finished with a rounded paving of stone on the top of the mattress work, 20 feet wide, and 1½ foot above average flood tide in the centre; the stone to be set on edge as far as the lowest level of the tide, the submerged part having a slope of 2 to 1. The stone pitching is to be carried up from the surface of the deposit of silt against the mattress work, so that none of the latter will be visible.

The remaining length of each limb, viz. 3,000 feet of the east and 2,800 feet of the west jetty, is to be consolidated by large blocks of cement concrete placed on the top. The blocks are to be 16 to 20 feet in length, 2½ to 4 feet thick, and enlarging in width by offsets as the jetties approach the sea from 5 to 13 feet. Before the blocks are put in position the surface is to be levelled up with stone and gravel to ordinary high-water mark. The line of blocks is ultimately to be surmounted by a continuous concrete parapet 3 feet to 6 feet wide, and 2½ feet to 4 feet high; but a sufficient time will be allowed for the settlement of the blocks before this is attempted. From the upper end of the concrete work to a point 600 feet above the sea end, the river and sea slopes of each jetty are to be formed of rubble stones, built with an inclination of 2 to 1, intermixed with broken stone and gravel; the pitching is to be carried from low water up to half the height of the concrete blocks. For the remaining 600 feet at the seaward end of both jetties the slopes are to be formed of a sloping gridiron composed of palmetto timber, sunk by filling the interstices with large stones averaging a ton in weight. On the sea slope a foundation, consisting of a willow mattress 100 feet wide and 2 feet thick, is to be prepared for the gridiron. The whole will be covered over with large stones, continuing the slope up to the line of concrete blocks in the centre. Both jetties are to be finished off at the end with T-shaped pierheads.

In the construction of the jetties the proportion of stone to willow was 1 : 5·32. A larger proportion of stone would no doubt have accelerated the formation of the channel by making the work more watertight and preventing the lateral escape of the current, but the difficulty of obtaining it necessitated the employment of the smallest amount practicable. The willows were brought down the river a distance of about 25 miles; the stone was at first obtained at New Orleans from the ballast of foreign ships, 21,000 tons being in this way secured; but the supply having been exhausted, limestone rock is now obtained from near Roseclair on the Ohio river, 1,300 miles above the mouth of the Mississippi. The method adopted of placing a complete layer of mattresses from end to end of the proposed jetty before the next layer was commenced, caused the deposit of silt to grow up at the back of the work as it progressed, and by the construction of wing dams extending into the current on the channel side a similar deposit was also

obtained on that side, and the formation of the deep-water channel hastened by confining the current. Of the entire length of the jetties all but the last 2,000 feet have received these protective deposits both on the river and sea side; so that 90 per cent. of the willow work is now embedded in silt.

The Author considers that experience has conclusively proved that the foundations are absolutely safe. that the sides of the work are protected by natural slopes formed of mud, sand, and clay deposited by the river, and that the tightness obtained for the jetty embankments is very nearly equal to that of the natural banks of the pass, the only difference being that the top mattress is not yet filled with sand, and therefore the leakage not completely stopped. It is considered that the permanency of the first 8,000 or 9,000 feet of the jetties will be secured by the pitching and dressing with stone.

It was at the sea ends that most difficulty of maintenance was to be expected, and in the course of construction the great amount of subsidence added to the magnitude of the work. At the extreme end 18 feet 9 inches of compressed mattress work subsided below the original surface of the bar, and during gales the top layers were displaced and thrown off by the waves. At this part the work being in the clear sea water of the gulf the deposit of silt no longer took place as rapidly as in the river. The attempt was first made to consolidate the work with large quantities of rock in pieces of 1 or 2 tons in weight, but this proved insufficient to resist the waves, and the capping of concrete blocks from 25 to 72 tons in weight was adopted.

A concrete mixer was erected on each jetty, consisting of a box 5 feet 9 inches cube, made of boiler plates, and suspended diagonally on trunnions. A cover at one of the angles was provided for, inserting and discharging the materials, while water is admitted through one of the trunnions.

A line of rails is carried down the centre of each jetty from under the concrete mixer for the transport of the material.

For the formation of a concrete block the broken stone on the top of the jetty is first levelled to the requisite height, and the mould, consisting of movable planking with a thin flooring, is built in place. As soon as the mould is complete, the concrete is brought down from the mixer in single charges of 2 cubic yards and tipped direct into it. The total time occupied in raising the materials from the wharf, charging, mixing, and tipping into the mould, was found to be seventeen or eighteen minutes for each charge. The concrete, after being deposited, was disturbed as little as possible, sufficient only being shifted to keep the layers horizontal. Ramming was dispensed with, as it was found that the vertical fall of 10 or 12 feet from the truck to the mould left it in a better state of compression. When the mould is full the surface is levelled with a rake, and four days later is rendered with Portland cement and sand in equal volumes for a thickness of 1 to 3 inches; it is then covered over with 1-inch boards, and not

disturbed for two weeks. At the end of this time the sides of the mould are removed, and the stanchions at the ends situated between two blocks are left to be removed at some future day, when the interval may be filled with rubble masonry. The concrete is made of broken stone, gravel, sand, and cement. The stone is broken by hand small enough to pass through a 3-inch ring. The cement weighed, on the average, 120 lbs. per bushel, with a tensile strength mixed neat of 278 lbs. per square inch after seven days. The composition of the blocks was fifteen parts of broken stone, 4·38 gravel, 8·28 sand, and 3 of cement, all measured by volume.

The contents of 100 cubic yards of set concrete are given as follows:—

Broken stone	80·75	cubic yards,	
Clean gravel	23·58	„	
Sand	44·57	„	
Cement	16·15	„	plus expansion;
	165·05	„	of dry material;

which make 103·94 cubic yards of concrete, from which it is seen that the coefficient of shrinkage is 0·629.

The excess of 3·94 cubic yards is taken up in the final induration of the concrete. The concrete weighs 160 lbs. per cubic foot when green, and 149 lbs. when thoroughly dry.

At the time of writing the Paper there were in place 2,097 linear feet of concrete blocks out of a total of 3,800 feet required on the east jetty, and 2,324 feet out of 2,800 feet on the west jetty.

A complete record has been kept throughout the work of the settlement of the jetties due to the weight of the blocks.

The general tendency appears to be to settle for the first ten days, and then remain nearly stationary.

An average of the settlements of eight groups of four blocks, each given in a table, shows 0·287 feet in the first period of from two to ten days, and a further amount of 0·195 feet in from two to four months.

A. T. A.

The Rhone, and rivers with beds liable to scour. By P. Du Boys.

(Annales des Ponts et Chaussées, 5th series, vol. xviii., 1879, p. 141, plate 1.)

The portion of the Rhone referred to by the Author extends from the St. Vallier bridge to the mouth of the river Ardèche, a length of 71½ miles. From the St. Vallier bridge to the mouth of the Isère, a distance of 16½ miles, the Rhone has a normal flow of 8,120 cubic feet per second, and a fall of 3 feet in a mile. From its junction with the Isère to the mouth of the Ardèche its normal

flow is about 11,800 cubic feet per second, and its average fall $4\frac{1}{6}$ feet per mile. The normal discharge of the Isère is about 3,530 cubic feet per second, and its waters are charged with a large quantity of silty sand. The other tributaries are torrential; they discharge very little water at ordinary times, but when they are in flood their discharge is very great, and they bring down gravel and boulders. The plain of the Rhone consists, for a considerable depth, of rounded flints, covered with a thin layer of soil. Regular lines of parallel embankments have been constructed between 1860 and 1873, placed about 650 feet apart above the junction with the Isère, and about 800 feet apart below it. When the river is low the fall of the water-line varies from nearly zero up to 26 feet per mile. The greatest depths are met with where the current runs close under a bank; and the rapids occur where the current crosses from one bank to the other. The rate of the normal flow varies between about $3\frac{1}{4}$ feet per second and $8\frac{1}{4}$ feet, and in flood time it has been observed as high as 13 feet per second. The direction of the stream is fairly parallel to the banks in flood time, but when the river is low it frequently shifts from one bank to the other.

The Author proceeds to consider at some length the force and the effects of scour, and the influence of the banks on the bed of a river.

Taking the case of a stream with an even flow, having a slope i and a depth H, in feet, the force F of scour on a square foot of the river bed is given by the equation, $F = 62 \cdot 4\, H\, i$.

The amount of material carried down increases inversely with the size of the particles; and the current produces the same effect on the particles forming the bed as if they were placed on an inclined plane with varying angle of inclination. The smaller particles travel fastest, and are generally found on the surface of the shifting layer; and when the force of the current decreases the larger particles come to rest first. The river bed adjusts itself so that the force of scour remains constant from one section to another. Assuming the case of a river of uniform flow and regular fall, when the banks are straight and parallel the scouring force of the current is only varied by irregularities in the current. When, however, the banks are curved the current is diverted to the concave bank, raising the level of the water near the concave bank and lowering it near the convex bank, which is readjusted when the curvature ceases. The scouring force of the current is greatest along the concave bank, but least at the beginning of the curve, and greatest at the down-stream end, where the water level is readjusted; the result along the convex bank is precisely the reverse. The upper current, directed obliquely towards the concave bank, presses on the lower layers of water possessing a less velocity, which produces a current at the bottom tending away from the bank; and this accounts for the increase of depth observed at the concave bank. Sharp changes in curvature of river banks produce abrupt variations in the force of scour, and consequent alterations

in depth; but when a river is in flood and the banks submerged, these effects are reduced by the counteracting influence of the upper layers of water. As floods vary constantly in their frequency and intensity, the bed of a river liable to scour must constantly vary, and the object to be attained is to keep these variations within limits. In a bend the main channel always follows the concave bank; but where the curvature changes abruptly the channel is variable; in a straight reach also the position of the channel is uncertain, being in a state of neutral equilibrium.

L. V. H.

The Regulation of the River Theiss, and the catastrophe at Szegedin. By C. Herrich, Ministerial Counsel.

(Magyar Mérnök-és Építész-Egylet Közlönye, vol. xiii. pp. 245, 305.)

The river is, to the Author's knowledge, unique in its kind—in Europe.

It has been regulated according to one well-matured and well-defined plan, of such magnitude as has never yet been attempted with any other large river in the world.

The success of the executed parts of the work, and the docility of the restrained river have been so marvellous, and so highly exceptional in the history of rivers, that the Theiss might well be the envy of all countries, and might afford highly instructive courses of study for any foreign hydraulic engineer.

The disaster at Szegedin has been brought about exclusively by the obstinacy of the municipality of that town, in declining their share of the great and comprehensive scheme of river works.

The length of the river under regulation may be said to be 740 miles, that of its valley 440 miles. The flood surface—during the first third of the century often all under water—extends over 6,000 square miles. More remarkable, however, than the extent of its flooded area, is the fall of this river. As soon as its flow reaches the plains of Northern Hungary, its fall is less than that of the Po near the sea, where it is called "il Po stagnante" and "il Po morto." Therefore, an "upper" Theiss, in the technical sense of the word, does not exist. On its lowest 50 miles or so the fall of the Theiss is only between a twenty-second and a twenty-fifth part of that of the corresponding part of the Rhine, and merely a seventh part of the fall of the "stagnant Po." In other words, on the highest part of this river, where there has been considered any object in starting works, the fall per 100 yards is $\frac{1}{2}$ to $\frac{1}{3}$ of an inch; at Tokay about $\frac{1}{8}$; and between Szegedin and the Theiss mouth, at Tittel at the Danube, about $\frac{1}{15}$ of an inch. The width of the northern point of the river between Tisza-Ujlak and Námény is 120 yards; about Tokay, 135 yards; between Szegedin and the Danube 250 yards. The depth at the first place is 30 feet; at Tokay, and thence right to the

Danube, with an increase of 1½ foot, and farther on a decrease of 3 feet in the middle reach, 37 feet throughout. In the first reach, it waters a section of 1,000 square yards; about Tokay, 1,200; between Szegedin and the Danube, 1,900. It carries, between Tisza-Ujlak and Námény, 1,800 cubic yards; between this place and Tokay, 3,300; between Tokay and Kesznyét, 4,500; between Szegedin and Tittel, 5,400 cubic yards per second. Floods exist, practically, through the whole year; and a couple of decades back, there were floods for ten years running.

Though surveys and projects were made in the last century, it was not before 1830 that any serious work was done. At this date, a surveying staff, under the conscientious engineer Vásárhelyi, was appointed to study the river. For more than ten years, thirty-five or forty engineers, assisted at times by large reinforcements, all well organised, kept accumulating such a mass of valuable information, that the learned and well-travelled author never mentions it without great admiration and pride. Indeed, he has loudly challenged the world more than once to match this mine of professional wealth. The bulk of the observations, plottings, computations, and estimates done, Vásárhelyi submitted the bold scheme he conceived to the general assembly of the proprietors, nearly all the nobility of the country. That this assembly soon came to constitute itself into one organised body is due to Count Stephen Széchényi, who, in 1846, prevailed upon Paleocapa—the prince of modern hydraulicians, as the Italians call him—to study the Theiss and examine the Hungarian engineer's project. Paleocapa tested, "admired," and subscribed to Vásárhelyi's scheme; not, however, without supplementing and refining on details.

The plan as settled between the two engineers was grand in its simplicity. Certain bold cuts were to be made. The river, on its entire length, was to be trained between banks; these banks to be in most places 1,000 to 1,200 yards apart, in no case less than 650, and in many as much as 3,300 yards. The dimensions were given for different reaches; the super-elevation of the banks over the highest known flood determined on different points: with the proviso, however, that these super-elevations should be further augmented as experience showed to be necessary; it being assumed that the floods of the regulated river would be sure to rise somewhat higher than formerly. The execution of a great number of the proposed cuttings was to be deferred till the effect of the new banks suggested their most appropriate sites. The plan embraced the widening of certain narrow reaches of the channel, and the correction of the mouth of the tributaries, and more especially the widening of the stream at Szegedin, from the present 170 yards to 250 yards, throwing back the banks to a width of 800 yards; the mouth of the river Maros, which at present enters the Theiss at a dangerous angle above Szegedin, to be transferred to the lower extremity of the town. The project suggests the main distribution of the future drainage and irrigation, and winds up with details of the more pressing part of the work.

Soon after the war of independence in 1848-49, the works were begun, strictly after this plan, with the exception of the Szegedin part. The best part of the nobility, being excluded from political life, concentrated their energies in advancing the work; and the government found it prudent to advance money. These works were vigorously pushed on till the year 1867, as vigorously and effectively as was possible with a limited and overworked staff, twenty-five or twenty-seven civil engineers in all. In 1867, the works were abruptly stopped, in consequence of the country's having recovered part of its ancient constitution. The political revival, and the construction and endless projecting of railways, &c., has deprived the Theiss company of its resources. The single great company was split into numerous local boards, which exhausted their feeble powers in futile debates, remonstrances, petitions, and finally lapsed into profound and chronic indifference, while the mechanical staff on the whole of the 740 miles was reduced to two engineers and their three assistants in all.

The works at the time of this Szegedin disaster, which was persistently foretold by all competent men for thirty years, were at the stage in which they were left in 1867, for anything the boards have done. The result is that, out of the 6,000 square miles of low ground, 4,200 square miles are protected. For drainage and irrigation purposes, however, not a trench had been dug, and not a pipe laid. Nevertheless, even this first instalment of the river regulation has benefited the country in a great measure. The alluvium of the Theiss has yielded wheat, maize, and tobacco, which products are equal or superior to the corresponding growths of the Bánát. By this means, the revenue of the country has increased by millions of florins annually, and national wealth has augmented by hundreds of millions.

The existing works have been severely tested. Each successive flood overtopped its predecessor by a few inches, as was foretold, but there has been a safe super-elevation of all the completed bank, over even the highest floods. In 1860, the floods encroached on 20 per cent. of the area protected. In 1876, when Szegedin had such a narrow escape, the floods broke only into 5 per cent. of the defended lands, the floods of 1877 into 4 per cent. of the secured area. In 1879, again, 5 per cent. of the protected lands, and the town of Szegedin were flooded. Four thousand square miles, then, have been safe this year; and only 200 square miles were flooded through the breaches of the neglected banks. Of these 200 square miles, nearly half are situated about Szalak-Taksouy and near Szegedin.

The cause of the Szegedin catastrophe is thus accounted for: the river was not widened, and the Maros tributary was not diverted to a point below the town, as persistently demanded by the engineers, and urged by the neighbouring local regulation-boards.

Of the town of Szegedin, the Author concludes, only that is lost which was decidedly bad; but the population is saved. Their share in the regulation work is being carried out now, and they

may eventually become worthy emulators of Budapest, so as to justify the saying of their wise and beloved monarch over the recent ruins—substituting the name of the town for that of the country—"Szegedin has not been, but is to be." ("Szeged nem volt, de lesz!")

B. S.

On the Preservation of the Ancient Bridges in the Regulation of the Course of the Tiber. By A. Vescovali.

(Il Politecnico, an. xxvii., p. 449.)

Signor Vescovali investigates the problem whether it is necessary, for the protection of Rome from inundation, to demolish or widen the ancient bridges over the Tiber. He regards this question as important, on the one hand, from the point of view of the archæologist; on the other hand, from that of the hydraulic engineer. If the rigid rule be followed for the execution of the works now in progress to widen the bed of the river from the actual width of 60 or 80 mètres, to the given minimum width of 100 mètres, it will be necessary either to demolish or to add new arches to the existing bridges. But if the object be so to lower the bed of the river as to restrain the floods within the quay walls, this demolition is not unavoidable.

The ancient bridges of Rome are:—1. Ponte Molle; 2. Ponte S. Angelo[1]; 3. Ponte Sisto[2]; 4. Ponte Cestio (on the right), and, 5. Ponte Fabricio (on the left) of the Isola Tiberina. This list does not include the Suspension Bridge, on the site of the Pons Æmilius; the ruins of the Sublician bridge, about 400 yards lower down the Tiber, or those of the Pons Triumphalis, at the bend of the river, west of S. Angelo. The nature of the bed of the river at the points crossed by these five bridges is described as "excavable" under the Ponte S. Angelo, and under the right-hand arch of the Ponte Fabricio. Under the other arches, the bed of the river is covered with the ruins of former bridges, and perhaps with brick platforms of masonry, and is described as "inattackable." The levels of the bed of the river at the five points named are, respectively, 17·16 feet, 12·17 feet, 2·97 feet, 11·94 feet, 8·71 feet, 3·59 feet, and 3·15 feet above the zero of the Ripetta fluviometer, which is 3·17 feet above the mean level of the sea.[3] The third and fourth of these figures apply respectively to the two middle, and the two lateral arches of the Ponte Sisto; and the last two refer to the right hand and the left hand arches of the Ponte Fabricio. The channels under the lateral arches of the Ponte Sisto have, however,

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[1] The ancient Pons Ælius.

[2] Pons Janiculensis.

[3] It is considered that the floods now amount to the volume of 3,000 metric tons per second, the low water volume of the Tiber being 100 metric tons per second.—F. R. C.

been recently excavated to a depth of 2·64 feet above the fluviometer zero.

The spans and areas of the apertures of these bridges are given in mètres, as it will be more convenient for comparison with the volume of the river than if they are reduced to English feet. They are as under:

	Spans.	Areas.
	Mètres.	Mètres.
Ponte Molle	71·50	641·52
Ponte S. Angelo	50·20	751·37
Ponte Sisto	69·40	739·70
Ponti Cestio e Fabricio, together . . .	59·20	913·17

It is estimated by Signor Vescovali that it is possible to enlarge the waterway of the Ponte S. Angelo, by deepening the bottom of the channel, to 1,084·87 square mètres; and that of the two last-named bridges taken together, to 995·05 square mètres. The waterway of the Ponte Sisto has been enlarged, by the work now in progress, to an area of 839 square mètres, by deepening the channel under the lateral arches by 2·92 mètres. Thus the Ponte S. Angelo, which has the least width of waterway of any of the bridges, has the greatest sectional opening in times of flood.

Signor Vescovali then argues that the Ponte S. Angelo does not cause any regurgitation of the water of the river; and states that the level of the water on the right bank of the Tiber, near S. Spirito, is sensibly higher than that on the left, in time of flood; a fact for which the rapid curve in the channel accounts. In the flood of October 31, 1873, which rose 13·73 mètres above the fluviometer zero, there was a difference of 25 centimètres in the level of the water on the opposite banks.

Signor Vescovali mentions the existence of a mass of ruin which forms a bar across the river between the Palazzo Altoviti and S. Spirito,[1] the crest of which rises nearly to the low-water level at that point, or 8 mètres above the bottom of the channel under the Ponte S. Angelo.[2] He considers that it is this bar, and not the bridge, which arrests the flow of the Tiber in this locality; and states that, in the flood of 1870, when the arches of the bridges were entirely under water, the river stood at the same level above and below the bridge of S. Angelo.

The Author is, therefore, of opinion that the first thing requisite for the proper regulation of the channel of the Tiber is the removal of those masses of ruin which prevent the river from deepening its own channel in time of flood. He states it to be a canon of hydraulic science, that in all rivers of which the banks are protected from erosion, and the bottom is formed of movable material, the bed becomes lowered by the force of the current in floods, and gradually fills up to its former level in that low-water state, to describe which there is no good equivalent for the Italian word "magra"

[1] This occupies the site of the ancient Pons Triumphalis.—F. R. C.
[2] Which would be down to the mean level of the sea.—F. R. C.

(feeble). With regard to the Tiber, from the site of the ancient Pons Sublicius to the sea, the bed is composed of material removable by a rapid current. Above this point, Signor Vescovali is of opinion that the actual height of the water is artificially kept up by the ruins, which prevent the scour from having a proper effect on the bed of the river. He states that when the tubular piles for the bridge for the Civita Vecchia railway were driven, fragments of pottery, ancient lamps, and numerous *stili*, of bone and ivory (with which the Romans were accustomed to write on their waxed tablets), were found in a stratum 1 foot deep which crosses the channel of the river at a depth of about 2 mètres below the zero of the Ripetta fluviometer. He considers that the stratum indicates the ancient level of the bed of the Tiber, and that in time of flood the level was normally excavated by the current down to a depth of 3 mètres below the present bottom of the Ponte Cestio, and 2 mètres below that at the Ponti Fabricio e Sisto.

Signor Vescovali, however, is of opinion that the ancient bridges over the Tiber were founded on platforms of masonry built across the bed of the river, which was probably partially diverted during the progress of the works. He gives reasons for this view, but insists on the necessity of ascertaining the fact, before proceeding with the costly works now in progress. He considers it probable that these platforms now exist, at a depth sufficient to allow of ample water-way being kept open through the bridges, if the ruins that encumber the bed of the river are removed. His opinion is that the now existing width of 50·20 mètres at the Ponte S. Angelo will be ample to carry off the water that comes through the newly-regulated channel 100 mètres wide, in consequence of the greater depth that the scour will then produce beneath the archways.

Signor Vescovali cites the example of the engineers Lombardini and Brighenti, who, in order to reduce the heights attained by the floods of the Arno in Florence, proposed, not the rebuilding of the bridges, but the removal of the masonry platform on which they stand, in order to allow of the excavating action of the scour of the river. He points out, however, the danger of undermining the piers of a bridge by such an operation; and remarks that the nature of the soil through which the Tiber flows is such as to have rendered necessary, in the recent construction of bridges to cross its bed, piling to a depth of nearly 40 feet (12 mètres) below the level of low water. Thus, while still in ignorance of the exact system on which the ancient bridges over the Tiber were built, Signor Vescovali holds that the bed of the river through Rome has been notably raised.

The Council of Public Works propose a clearing of the bed of the river limited to a level of 1·50 mètre above the zero of the fluviometer at the Ripetta, from which point the profile is to be horizontal as far as the Ponte Molle, going up stream, and to fall with the gradient of 0·40 per kilomètre towards the sea. According to this plan, the bed of the river at Marmorata (below the site of the ancient Sublician Bridge) will be 0·10 mètre above the zero of

the fluviometer. At the two island bridges it will be 0·29 mètre above, and at the Ponte Sisto, 0·50 mètre above that fixed point. Signor Vescovali urges that the depth requisite below the bridges ought to be at least 3 mètres below the zero of the fluviometer. He holds that if the channel is clear to this depth—which is the level of the platform of the Ponte S. Angelo, and of the right arch of the Ponte Fabricio—ample water-way will be secured for the river without demolition or enlargement of the bridges. He is of opinion that the course of the channel should be regulated, according to the plan of Signor Cesarini, from the Ponte Molle to the Canal of Fiumicino; and that in consequence the low-water level would be reduced 4 mètres at Ripetta; that a depth of 5 mètres would be retained in times of drought; that the level of the floods would be reduced from 4 to 5 mètres below that attained in 1870; that the level of the subterranean waters in Rome would be lowered by 4 mètres; and that navigation would be practicable from the sea to the city of Rome.

F. R. C.

[NOTE.—As the zero of the Ripetta fluviometer is only 0·97 mètre above the mean level of the sea, the bottom of the channel of the Tiber in Rome, according to the above suggestion, would be 2·03 mètres below sea level. Referring to the account given (Minutes of Proceedings Inst. C.E., vol. lvii., p. 360), of the gradual depression of the eastern coast of Italy, the question arises whether a similar movement in the valley of the Tiber may not have occurred, in which case the increased damage caused by floods would become readily intelligible.—F. R. C.]

Condition of the Rivers and Navigable Communications in Hungary. By L. BODOKY, Inspector of Public Works.

(Magyar Mérnök-és Épitész-Egylet Közlönye, vol. xiii. p. 35 *et seq.*)

The Danube.—A considerable part of this great river becomes difficult for navigation during the dry season. Transshipment is usually resorted to between Pressburg and Gönyö, on account of numerous islands. Above Budapest there are several slighter obstacles from sandbanks and shallows. Below Budapest, along the large island of Csepel, the navigable channel of the river is now being improved. Below Csepel there are three trying reaches (between R. Almás and D. Vecse, Uszod and Gerjen, Illok and Palánka). But all these places, comprised between Gönyö and Ó-(old) Moldva, allow about 6 feet depth for steamers at low water. The greater obstructions occur at six places between Ó-Moldva and the Iron Gates. The Author gives the details of these obstructions, and particulars about the masonry spurs, rock-blasting, a few cuttings, &c., finished and still in progress as far as the annual funds at disposal allow.

Although the river is maintained by the Government, there never yet existed a comprehensive scheme of improvement. At

some places banks were secured by spurs and pitching; at others, weak arms were cut off or dredged: all in a perfunctory manner. The Author shows how, by following a consecutive plan, much could be done at a small annual outlay. The shallow side channels should be closed up. This would save the expense of the annual dredging, and the invigorated and more permanent flow would show where best to concentrate operations; thus avoiding the squandering of money on small works which at present become useless in a couple of seasons from the shifting of the main stream.

From 415 yards at the site of Tierney Clarke's suspension bridge, the width of the river increases, within a mile or two, to 1,640 yards, in two nearly equal branches. This wide, sluggish, and shallow reach, combined with the severity of continental winters, was, within a short time ago, the exclusive cause of the floods in and near the town. The floating ice, arrived at the shallows, relaxes its speed, and, blocking the way to the following masses, gets pressed down to the bed of the stream, consolidates into a bar, and throws the water over the best part of the town. The regulation of this portion of the river was begun in 1871, and is now, with the exception of a few minor details, completed. The chief part of the works was the cutting off of the left arm and the reducing the width of the right. Many miles of stone quays and banks were built soon after 1871. Their greatest height above low-water mark is now more than 24 feet.

In regard to works for preventing inundation, there is the same want of consistency as in the casual works for improving the navigation. Of over 2,000,000 of acres of flood-area scarcely more than three-fifths are protected by embankments; and even these are bad, as every spring flood breaks through them at "innumerable" places. Besides being too flimsy they are of insufficient height. A hue and cry is raised every year "all over the country" at these inundations, and then everybody subsides into constitutional inactivity. These banks are in the hands of local companies, several of whom the government has been assisting.

The Author concludes his remarks on the Danube by giving the "principles" settled between the Austro-Hungarian and the Turkish governments concerning the works to be done at the Iron Gates.

Other Rivers.—Of the four chief tributaries of the Danube[1]—the Morva, the Vág, the Garam, and the Ipoly—only one, the Vág, has been subjected to any improvement worth notice. The

[1] After the Theiss, the largest are the Drave and the Save. The Author writes that he omitted these rivers, because the Save, and great part of the Drave, is under Croatian autonomy; and because, on that part of the Drave which is directly under Hungarian superintendence, nothing particular has been doing of late. The Hungarian Government spend annually about £2,000 on their part of the Drave for clearing the bed and cutting off sharper bends. The Save is navigable for steamers up to Sziszek, on 370 miles, the Drave up to Légrád on 150. Government contemplate to start shortly works of national importance, specially on the Save.—B. S.

Government had efficient surveys made, and has spent, since 1874, at the rate of £20,000 per annum on cuttings, protection of banks—both with a view to navigation—and has assisted some local companies in their work against the floods. But there are only 50 miles of embankments made as yet.

Of the lesser tributaries of the Danube and the lakes, the Author gives lists of names of areas to be protected from floods, and of some schemes, and interesting particulars about the drainage of lakes Balaton and Fertö, the latter of which is being laid dry.

On the Theiss, the cuts, to the number of 113, and an aggregate length of 83 miles, have been done by Government. In a length of 750 miles, they shorten by 300 miles. On these works Government spent £690,000, and for further works there have been £70,000 voted annually for three years. On 1,000 miles of embankments twenty-nine local companies spent over £2,000,000, besides natural service (earthwork and 'lead,' &c.). The average cost of reclaiming land is about £1 7*s.* per acre (the highest £10 4*s.*, the lowest 10*s.*).

Tributaries of the Theiss.—The Szamos regulation would protect 475,000 acres. Of the projected cuts some are made already. At the Bodrog, Ondova, Tapolya, and other three rivers, a good deal has been doing, but still far from enough, even in regard to floods. The three rivers Körös (White, Black, and Fast), and the Berettyó, show altogether rather favourably; as out of their united flood-area of over 900,000 acres, a little over 700,000 acres are protected. There have been some long straight canals dug in this river system. The cost cannot now be ascertained. At the Maros twenty-nine cuts have been made, with an aggregate length of 23 miles. These reduce a former length of 430 miles to 162 miles. The banks are protected by stone pitching on about 4 miles. There are, in most parts of the low lands, embankments; but they are badly maintained. The Béga canal, made in the middle of the last century, for draining and navigation purposes, is not yet navigable. Though there has been much useful work done since 1867, the proper completion would cost £385,000, which sum is very likely to be voted by Parliament. For the regulation of the Béga and the Temes, with all the tributaries of the latter, a joint company was formed in 1871. The area to be protected is 600,000 acres. The necessary cuts and embankments are described by the Author, who also gives the estimates. Of these works a great part is completed already, the Company having spent £40,000 since 1871. An interesting series of regulation works has been begun at the Rába and its tributaries. The complete works are estimated at over £600,000. Twelve companies have recently been concessioned, most of them along the Danube. Of their working little is known yet, though the aggregate area to be saved by them from floods is over 200,000 acres.

Navigable Canals.—The Francis canal (of which a full description is given in the preceding volume of the Budapest Minutes),

has been doing well. Its traffic has gone on increasing at the following rates: in 1876, over 246,000 ton-miles; in 1877 over 350,000; in 1878 over 600,000 ton-miles.

The canalisation schemes still waiting for better times are the following: 1st. The Upper Theiss, Érvölgy,[1] and Körös Canal, between Péterfalva and Gyoma, 141 miles long, eighteen locks; object, navigation, and irrigation; at £1,200,000. 2nd. Between T. Lök and Gyoma, the Theiss, Hortobágy,[1] and Körös canal, 77 miles, two locks, irrigation being the chief object, capital £690,000. 3rd. The Szárazér[1] canal between Arad and Mártély, ten locks on 67 miles, for navigation, drainage, and irrigation, estimated (including a feeder) at £860,000. 4th. Two alternate projects of an Upper Danube and Theiss canal, between Haraszti and either Csongrád or Szegedin, 97 or 106 miles. The first is estimated (including works for irrigation) at £2,568,000, exclusive of irrigation arrangements (with level bottoms between locks) at £1,610,000. B. S.

Harbour at Batavia.[2]

(Extracted from the Specifications and Annual Reports of the Dutch Government Engineers.)

The works for the Batavian harbour, the construction of which has been undertaken by the Dutch Government, are situated at Tandjong Priok, and consist of a harbour enclosed by two piers, together 4,076 yards long; an inner basin 1,421 yards long, and 191 yards wide, with two wharves, which will together have a length of 1,518 yards. Warehouses, cranes, railways, &c., will also be provided.

The harbour will be connected with the capital of Batavia by a railway about 5 miles long, with double line, a road 50 feet wide, and a ship canal with a towing path.

The sea piers are intended to be formed by a rubble mound, 23 feet wide at low-water level, with slopes of $1\frac{1}{2}$ to 1, and 2 to 1, with concrete blockwork above low water, 6 feet 6 inches wide and 5 feet high; the toe of the concrete work being protected by footings of rubble deposit, the slopes above low water to be hand-pitched. They will require for their construction about 1,046,400 cubic yards of rubble stone, 83,843 cubic yards of concrete, and 100,063 cubic yards of sand.

To form the outer harbour and the inner basin, it will be necessary to dredge about 7,848,000 cubic yards of stuff, and to excavate about 523,200 cubic yards. In addition to which, 13,080 cubic yards of stone will be used for the slopes.

For the wharves, 20,000 piles, 13,080 cubic yards of sand,

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[1] Dry bed of a stream of a similar character to those in the African deserts.

[2] Since this Abstract was in type an illustrated description of these works has appeared in "The Engineer," Nov. 14, 1879.

57,552 cubic yards of concrete, and 18,312 cubic yards of brickwork, will be required.

The cost of the plant required for the construction of the harbour is estimated at about 1,000,000 florins (£83,000).

The railway, road, and towpath, between Tandjong Priok and the capital will necessitate the removal of about 784,800 cubic yards of ground, and several fixed and movable bridges. To make the ship canal, 218,436 cubic yards of ground will have to be excavated, and 919,530 cubic yards dredged. The enormous quantity of stone which will be required will be procured from the trachite rocks at Merak, in the straits of Sunda. The quarrying will be executed as follows: Sixteen boreholes will be made daily by rock-boring machines worked by compressed air, the compressors being driven by portable engines. Each boring tool will make a hole 1 foot deep in the hard rock in two minutes. The boreholes will be loaded with dynamite or lithofracteur, exploded by electricity. The pieces of rock, which will be again broken by dynamite when too large, will be loaded by steam cranes into wagons, which will transport them to three stagings in the sea (built on screw piles, with iron superstructure), where they will be received by hopper barges for conveyance to Tandjong Priok. These hopper barges are iron steamers of 600 tons capacity, provided with compound engines of about 300 HP., and with a speed of about 8 English miles per hour. Six hopper barges will be on duty at Merak, each of which will convey a cargo of stone to Tandjong Priok at least three times per week. There the stone will be discharged, where required, by the hoppers, their position being fixed by observations from shore.

When the deposit attains a height which no longer permits of the discharge of the hoppers in the usual way, that operation will be performed by two steam cranes on the deck, which will deposit the stone directly in the required place—or, should this not be possible, upon a wharf, whence they will be removed by wagons.

It is estimated that the stone put into the work, as described, will cost, at a maximum, 5·80 florins (9*s.* 8*d.*) per cubic mètre, while the usual price of stone in Batavia is about 7·50 florins (12*s.* 4*d.*)

The dredging in the harbour is to be executed by three steam dredgers of unusual power, built at Glasgow. They have compound engines of fully 300 HP., and all the secondary operations are performed by steam power. The buckets hold $\frac{1}{3}$ cubic mètre each, and a weight of 1 ton. On their trial the dredgers must lift 600 tons of stuff per hour; and in the harbour it is estimated that they will dredge 480,000 cubic mètres per year (200 cubic mètres per hour, ten hours per day, two hundred and forty days per year). The dredged stuff will be taken to sea by hopper barges, six in number, similar to those above described. The three first-class dredgers are also to be employed to remove the coral reefs in the outer harbour, for which object some of the buckets are to be replaced by steel claws, each weighing

1 ton, with which the reefs, after being first shattered by dynamite, are so broken up, that they can be dredged. The inner basin at Tandjong Priok is to be excavated entirely on land, the present height of which is about 6½ feet above low water. In the beginning the ground will be excavated by manual labour, but afterwards by dredgers, brought from Europe for the purpose. These dredgers, the engines of which are about 160 HP., are provided with screws, and have a speed of about 6 miles per hour. They have been built at Glasgow and Delfshaven, and have, like the first-class dredgers, to come directly to Java with their own engines, so that they may be regarded as thoroughly seaworthy. Whilst, however, the first-class dredgers are to retain in Java their character as sea-going ships, the second class are so constructed that the forward portion can be removed on their arrival in the Batavia roads, thus rendering them better adapted for their work inside, as well as in the outer harbour. The power of these dredgers being about one-third that of those of the first class, they will dredge about 200 tons per hour. The bucket ladder projects about 2 mètres in front of the vessel, so that it can dredge its own channel before it. Steel claws are also provided for these dredgers, to enable them, if necessary, to remove large pieces of stone. The surplus dredgings will be deposited in barges, and towed out to sea; but if adapted for banks, they will be discharged on shore by a stream of water through a long shoot, with an inclination of one-tenth, by which means they will be spread over a distance of about 25 mètres (82 feet).

Dredgers of the same description will be also used for the construction of the ship canal. The dredgers must first cut themselves a channel on the site of the canal, through the different rivers which flow into the sea between Batavia and Tandjong Priok, and afterwards make the canal itself, while the dredged stuff cast on shore will go to form the railway, the road, and the towing-path. Until the arrival of the dredgers, the work will be carried on by manual labour.

There are four steam dredgers of the sort described, and two smaller steam dredgers, besides twelve hopper barges without steam power, and two tugs for the work in the inner basin, and in the canal.

The quay wall in the inner basin is not the least comprehensive work that has to be done. The many thousand piles required will be driven by Morrison and Boeff and Appleby's steam pile-drivers. Before driving the foundation piles, the space inside the cofferdam will be machine-dredged to a depth of 1 mètre below the bottom of the basin. The foundation piles will be sawn off by steam power at 6½ mètres below datum. To obtain the very large quantity of concrete required for the wharf wall and for the sea piers, four sets of machines will be provided, capable of delivering 240 cubic mètres of concrete daily (in ten hours). From these mixers the concrete blocks will be transported by rail to the piers.

Lime, cement, and brick kilns will also be erected at Tandjong

Priok, together with extensive workshops. A floating iron dry dock will be constructed in Europe, and brought to Java in sections. Other workshops will also be required at Merak. Large coal depôts will also be constructed, with jetties, railways, &c.

Special measures have to be taken to preserve the health of the workpeople. Towards sunset they are all taken by steamers and barges to Batavia, and brought back in the morning, so as to avoid the unhealthy night malaria. Two artesian wells have been sunk at Tandjong Priok to provide them with pure water.

The works are expected to be completed in nine years.

Up to May 1878, the date of the latest reports, the railway between Batavia and Tandjong Priok had been so far completed as to be serviceable for transport; the canal had been excavated so far as it could be done by manual labour; the two artesian wells had been finished, together with the necessary pipes; and a number of temporary wharves had been erected. The stone deposit had been commenced for the west pier, which had been extended to 200 mètres from shore, the settlement being found much less than had been anticipated. The large dredgers, and twelve hopper barges, a large tug steamer, and the floating dry dock, had also arrived from England, and were being fitted for work with all expedition.

At Merak (the quarries), cholera had been prevalent amongst the workpeople, and some delay had been caused by it. Nevertheless, the necessary plant, railways, cranes, wells, wharves, &c., had been established; 20,489 cubic yards of ground had been removed by 5,174 lbs. of dynamite (9,127 shots). The regular working of the quarries, for the supply of stone for the piers, began in the end of March, and by the end of April 11,800 cubic yards of trachite, and 7,848 cubic yards of ordinary excavation had been removed by the use of 9,064 lbs. of dynamite (16,734 shots).

D. H.

The Hungarian Harbour at Fiume. By A. Hajnal.

(Magyar Mérnök-és Épitész-Egylet Közlönye, vol. xii., pp. 201, 218, and 3 tables.)

During the second quarter of the present century an extent of 12½ acres of harbour and the Fiumara canal were built. When this part of the Hungarian coast was being connected by railway northwards and eastwards, the parliament voted £1,300,000 for harbour extension works. Of this sum it was estimated that £750,000 would be spent by the end of 1880. Up to the end of 1877 a sum of £414,000 had been expended. The completed works are to extend the area of the harbour to 82½ acres, and that of the canal to 12½ acres, with an aggregate length of 5,850 yards of quays. The surveys, soundings, plans, and estimates were made by the Hungarian government engineers, examined and partially modified by a French engineer, M. Pascal; and the works are being

executed by the "Entreprise générale de chemins de fer et de travaux publics," under the superintendence of the government agents, who also prepare the plans of details of construction. The harbour is safe, by reason of its position, from the "bora," and protected by a good mole from the sirocco. It is contiguous to the railway station. The ground is very favourable, so that slips are of rare occurrence. The average depth of the water is 10 fathoms. A full description is given of the working of two neighbouring quarries, which, with the present means, are equal to a turn-out of 4,000 tons of material daily. (In these quarries there are 7½ miles of a 2·625 feet gauge railway). The top of the rubble mound foundation is 21·32 feet below datum. On this, up to the water level, masonry of concrete blocks, 12·14 by 4·92 by 3·61 feet, is raised. The blocks are set in Santorin mortar: 11 parts of Santorin earth, 4 of lime, 1 of sand. Of three thousand two hundred and eighty of these blocks, made at the end of 1877, only five broke during transport. With the present appliances sixteen of these blocks can be laid daily. The height of the walls above datum varies between 5·35 and 8·92 feet; the batter is 1 in 6. To reduce the damage from unequal settlement, the foundations are made in separate lengths of about 30 feet each.

The traffic in 1871, exclusive of vessels of 50 tons, was 4,331 vessels (3,815 sailing, and 516 steamships), gauging 281,000 tons. Between 1872 and 1877 the number of the vessels fluctuated between 5,154 and 5,573, and the tonnage between 318,560 and 366,000.

B. S.

The Ocean Pier at Coney Island. By C. Macdonald.

(Transactions of the American Society of Civil Engineers, vol. viii., p. 227.)

The Coney Island pier, the first of its kind in the United States, is situated at Gravesend, a suburb of New York and Brooklyn, facing the Atlantic, and its object is to afford a means of landing from steamers connecting with all points of New York harbour and at the same time to serve as a promenade and bathing pavilion. At the shore end it is 120 feet wide between the centres of the outer piles, and 120 feet long; thence to the mid-section, a distance of 320 feet, the width is 50 feet. At this section the width is 83 feet for a length of 100 feet; from thence to the pier-head the width is again 50 feet for 320 feet in length, and the pier-head is 100 feet wide by 140 feet long. A double row of wooden guard piles extends around three sides of the pier-head, projecting seawards so as to form a dolphin protection and landing stage in advance of the ironwork. There are two floors throughout, except at the shore end, the lower one being 12 feet and the upper one 24 feet above high water. The lower floor is used for embarkation at the outer end, and for bathing purposes elsewhere.

One of the special features of the general design is the complete

roofing in of the promenade deck, and the erection of refreshment and other buildings of considerable size, exposing a large surface to the Atlantic storms—a rather bold innovation in so light and open a structure. In details also this pier offers many points of difference as compared with English works: thus, the piles are thin wrought-iron tubes, instead of stout cast-iron columns; and the girders are heavy rolled joists, instead of light lattice trusses. The piles were sunk by water-jet; the disks at the base were of cast iron, 2 feet in diameter and 9 inches deep, having a socket on the upper side to receive the lap-welded, $8\frac{3}{4}$ inches diameter by $\frac{3}{8}$ inch to $\frac{1}{2}$ inch thick, tubular pile, and on the lower side a conical projection strengthened by ribs, through which an opening 2 inches in diameter is left for the water-jet. This method of sinking piles was, it is claimed, first used in sinking the piles for a wharf at Matagorda bay, Texas, in the year 1852. The 10-inch and 15-inch rolled joists forming the superstructure are 20 feet long, and weigh from 35 lbs. to 50 lbs. per lineal foot. Transversely the piles are placed about 16 feet 8 inches apart, and are braced together by 6-inch beams and tie-irons.

The timber floor consists of 12-inch by 3-inch pine joists, spaced 2 feet apart, and planked with 6-inch by 3-inch battens. No provision is made for expansion in the 1,000 feet length of pier, beyond slotting the holes in the rolled joists through which pass the bolts attaching the joists to the piles. This is the more noteworthy as the range of temperature is so much greater in America than in England—150° is mentioned in the most recent American bridge specifications.

At the pier-head the water is 16 feet deep, and the piles in this section are about 57 feet long, giving a depth of 17 feet in the sand. For setting the piles a travelling derrick, illustrated in the Paper, was used with much success. When no serious obstructions were met with, the time expended in sinking a row of piles, placing the iron beams and temporary track, and rolling out for the next row, was six hours during day-time, and eight hours on the night shift. In clean sand, the piles went down about 3 feet a minute until a depth of 12 feet was attained, and the rate then rapidly diminished until, at 18 feet, great loss of time was involved. Piles with 2 feet 6 inches and 3-feet disks were tried, but they took much longer to sink than those with 2-feet disks.

No details of cost are given in the Paper.

B. B.

Pivoting Excavator. By A. Marnier.

(Revue industrielle, vol. x., p. 355.)

The pivoting excavator, designed by M. Sayn, consists of an iron truck running on six wheels coupled, which carries a platform capable of turning freely round a vertical central pin, which platform bears the engine, the machinery for the transmission of

motion, and the framework supporting the excavating gear. The machine can excavate in front by means of its chain of buckets, discharging the material behind by a movable shoot into wagons, thus enabling the whole of the bottom of a cutting to be used for the removal of the earth. It can also work sideways along the slopes of a cutting, to widen it; in this case the excavated stuff is delivered into a long train of wagons at the side. It can be modified, by altering the buckets and using a long beam for carrying them, when it is available to work at the edge of a cutting for widening it. The machine can also be readily transferred to a barge, and by varying the form of bucket can be employed as a dredger. Lastly, by substituting a jib for the beam, the apparatus can be used as a movable steam-crane turning on its axis. The object is to economise plant by making a machine that, with only slight modifications, shall be capable of satisfying several different requirements.

L. V. H.

Drawing Piles in Cuxhaven Harbour. By H. Lentz.

(Deutsche Bauzeitung, 1879, p. 340.)

The drawing of piles, and stumps of piles, always a difficult operation, is particularly troublesome at Cuxhaven on account of the fine drift sand, which holds them remarkably fast. A trial pile, 3·23 feet in circumference, driven to a depth of 15·7 feet, was extracted by a pull of 7 tons 16 cwt. after it had remained only twenty-three days in the ground. Numerous piles, on the average 17 inches in diameter, required pulls of from 23 tons 10 cwt. to 28 tons 15 cwt., after having remained embedded from ten to twenty years at a similar depth; while one stump of the same dimensions, which had remained in the ground over fifty years, could not be stirred by a pull even of 43 tons 15 cwt. This latter pull was the greatest which could be exerted by the apparatus about to be described.

An old rowing barge, strengthened by a strong deck and numerous iron knees, was arranged to carry amidships a pair of sheer legs, to which two pulleys were attached. Over these ran a chain 0·63 inch in thickness, from the drum of a windlass geared in the ratio of 50 to 1, and carried a loose pulley so that four men could exert a pull of from 5 to 7·75 tons. On each side of the windlass was a tree trunk of the average diameter of 21 inches, laid slanting over the barge, and projecting 20 feet over the far side. The trunks were fastened firmly to the deck. The outer ends projected slightly over the near side of the barge, and were connected together by an oaken beam, 12·2 by 12·9 inches square, which latter was fastened by means of a chain to the pile which had to be drawn. The far ends of the trunks were loaded with balks of timber

which served as a counter-weight when the apparatus was at work, but at other times floated in the water. The chain was made fast to the pile at low-water, and as the tide rose the barge got more and more immersed, and inclined towards the pile, and the counter-weight rose out of the water, the pull increasing correspondingly. As soon as the pile began to move, the chain from the windlass was also slung on to it, and the pull of this latter was added to the hydraulic pressure of the rising tide. Under fortunate circumstances, with this apparatus, two piles could be drawn consecutively on one tide. In Cuxhaven the difference between high and low water is on the average 9·2 feet, and the flow lasts five hours thirty-four minutes.

In order to avoid the numerous inconveniences of this apparatus, the Author, after many trials, construoted a much simpler one. It consisted of a large timber box, well braced internally, 22 feet 6 inches long, 19 feet wide, and 6 feet 6 inches deep, provided with a slit or bay 34 inches wide, reaching from the middle of one of the longer sides to beyond the centre of the box. When totally immersed, it was capable of exerting a pull of 59 tons. By means of an oak beam, laid over the centre of gravity of the box and attached by chains to the piles, these latter could be floated out as before. In some cases pulls of 50 and 55 tons had to be exerted before the pile could be moved; but, in no instance was the full power of the box, viz. 59 tons, brought into requisition.

G. C. V. H.

Dock Machinery and Plant at the Port of Antwerp.

(Association des Ingénieurs sortis de l'École de Liége.)

The tidal portion of the Scheldt and the Port of Antwerp [1] have previously been noticed, as well as the new works [2] now in progress for the improvement and extension of the river and dock accommodation there. In a voluminous handbook,[3] compiled for the recent visit of the Liége Association of Engineers to Antwerp, information furnished in detail under the foregoing heads is followed by an account of the extensive mechanical appliances employed at the existing docks, the railway accommodation, and the principal industries making up the trade of the city and port.

Dredger, Tugs, and Pumps.—The docks are kept clear to the

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. liii., p. 313.
[2] *Ibid.*, vol. lvii., p. 376.
[3] "Anvers: aperçu sur ses Installations Maritimes et son Industrie." By MM. Em. de Keyser, Paul de Wit, F. van Peteghem, and P. Sauvage. August 1879, pp. 160, and 9 plates.

proper depth by a single dredger, raising annually 31,400 cubic yards of spoil, which is discharged into the river, 5½ miles down, by a screw hopper-barge. Three small steam tugs tow vessels entering the docks to the berths assigned them alongside the quays; they are found so convenient that their number will be increased. The three additional dry docks, opening out of the largest (Kattendyk) dock, are being constructed with convex floors and side drains, instead of the usual "invert" with centre drain; and the keelblocks, thus conveniently kept high and dry, are made of three hollow cast-iron wedges with strengthening ribs. For pumping the docks out either through their whole depth or only below low-water level, a horizontal two-cylinder engine of 250 HP. is employed, working eight piston-pumps in pairs, which deliver together 11,800 tons per hour, and empty the largest of the three existing dry docks from the ordinary flotation line in two hours. A smaller engine, working about one hour in every three, keeps the docks drained after pumping out.

Hydraulic Machinery.—Around the docks an area of altogether 6¼ acres is covered with sheds for discharging and storing goods, and the roofing is being further extended. Four fixed hand-cranes, one for 40 tons load, were all that were in use till 1876; six 1¾-ton steam-cranes were then added, running on rails of 7 feet 9 inches gauge, three for discharging copper ore, and three for shipping coal. Hydraulic power has now been laid on by Sir William Armstrong and Co., and its use will be largely extended. A two-cylinder horizontal condensing engine of 150 HP. pumps water into the pressure pipes at 700 lbs. per square inch, the accumulator having a ram of 20 inches diameter and 23½ feet stroke; there is already a length of more than 3 miles of pipe, ranging from 6 down to 2 inches diameter. Fire-cocks are provided every 50 yards, with attachment for jet-nozzle; in the event of fire the accumulator is shut off, and the water pumped through an air vessel at the rate of 300 gallons per minute, under a pressure of 180 lbs. per square inch. For working the swing bridges and dock gates, two-cylinder oscillating hydraulic engines with combined piston and ram are employed. At each bridge 5-ton hydraulic capstans are provided, for hauling vessels more speedily through the dock entrances, and are worked by three single-acting oscillating cylinders; an 11-ton capstan of variable power is fixed at the old dock entrance. For hauling balks out of the water at the timber dock, and shifting the portable hydraulic cranes, 1-ton capstans are provided, each worked by a pair of double-acting oscillating cylinders; the bed-plate of the capstan head carries all the mechanism on its underside, so that by merely tipping it up the whole is accessible. There are six portable hydraulic cranes, with arrangement for lifting either ¾ ton or 1½ ton; and water pressure has now been applied to the 40-ton crane previously worked by hand. At the Kattendyk dock is a sheer-legs 90 feet high, to lift 120 tons; a three-cylinder hydraulic engine works the chain barrel, and also shifts the back leg for adjusting the inclination of the two front legs.

Electric Lighting.—From the end of 1878 an electric light erected at the entrance of the old docks has been in regular operation for three to three and a half hours at every high tide occurring in the night, for facilitating the entrance and exit of vessels. It consists of two lamps—a Siemens and a Serrin—supplied respectively by a Siemens & Halske and a Gramme electric machine, both driven by a three-cylinder hydraulic engine identical with those working the 5-ton capstans. Either machine takes from 2 to 3 HP. to drive it; for safety 7 HP. is reckoned upon for the two together. The consumption of carbon in each lamp is from $1\frac{3}{4}$ inch to 2 inches per hour; the carbon in the Siemens lamp is $\frac{3}{8}$ inch square, and that in the Serrin $\frac{1}{2}$ inch square or round.

The total outlay upon the improvements and extension of the existing dock accommodation during the last six years has amounted to about £376,000, including £85,000 for plant and machinery; and £280,000 besides has been expended in acquiring additional land on this north side of the city. The rectification of the river quays and the construction of the new south dock will involve on completion further extensive additions of plant and machinery, including special coal-shipping appliances with ample sidings for trains of wagons; for these the new quay to be constructed north of the Kattendyk dock entrance will probably be found the most suitable.

Railways.—The several goods stations adjoining the old docks comprise altogether 120 acres, with 25 miles of railway, and can accommodate nearly six thousand wagons without blocking the main lines; they are furnished with hydraulic cranes and capstans. Twenty-five goods trains are despatched daily, and the same number arrive. The traffic has about doubled since 1870, having exceeded 2,000,000 tons in 1878. There is also an engine shed capable of accommodating thirty to fifty locomotives; and a locomotive repairing shop, recently furnished with the electric light. The present temporary south station, adjoining the new south dock works, will assume largely increased importance on the completion of this dock; and the present Waes station on the river quay, midway between the new south dock and the old north docks, will be removed to an improved site on the new quay wall when completed, adjoining the intended floating landing-stage.

Industries.—For 8 or 10 miles above Antwerp the banks of the Scheldt and the Rupel are occupied by numerous works, including brick, tile and pottery works, copper, sulphuric acid, guano, and cement works; and also by shipbuilding and repairing yards for sea-going and river craft; employing not less than sixteen thousand hands altogether. Within the city are distilleries, sugar and sulphur refineries, rice and starch works, candle and tobacco factories, oil mills, wool-combing works, diamond-cutting shops, silk and carpet mills, varnish and animal charcoal works, &c.

The brick, tile and pottery manufacture holds the first place for antiquity and importance; a bed of vast extent and from 50 to 100

feet thickness furnishes clay of a slightly bluish dark grey tint. From this the bricks for the river quay walls are being made by machinery at the rate of thirty thousand to forty thousand per day; tiles and quarries are made from the better portions of the clay, and Portland cement from nodules of clayey limestone contained in it. At the Hemixem copper works, the only establishment of the kind in Belgium, the cupreous residues of pyrites, that have been burnt for sulphur at chemical works elsewhere, are treated by the wet process for precipitating upon iron the remaining copper they contain. The resulting copper precipitate, containing 80 to 90 per cent. of copper, is remarkable for its freedom from arsenic, antimony, and other impurities; and is much employed by French manufacturers for work requiring the best quality of copper. The residual "purple ore" from the wet process contains when dry from 55 to 60 per cent. of iron, and is entirely free from phosphorus; the Ougrée blast-furnaces, Liége, were the first to smelt it for cast iron, and it is now so dealt with also in the ironworks of the Ruhr district and of Westphalia; it is used too as an oxidising agent for the dephosphorisation of iron or steel made by the new direct process, and in the manufacture of malleable cast iron, and as fettling for puddling furnaces. At Hoboken, 2 or 3 miles above Antwerp, the Cockerill Co. of Seraing have an extensive shipbuilding yard. The Peruvian guano manufactory at Burght is large and well planned; and the sulphuric acid required in the manufacture is made on the spot, the lead chambers with the rest of the appliances being constructed on a remarkably large scale.

Within Antwerp, the Borgerhout stearine candle manufactory has since 1850 increased its production a hundredfold. Diamond cutting, introduced into Antwerp in 1476, is now carried on there in thirty shops. Of eight rice mills altogether in Belgium, six are in Antwerp, working from 40,000 to 50,000 tons of crude rice per annum; and other works manufacture starch from rice. The distilleries turn out about 13,200 gallons per day, and contribute together about one-third of the entire excise duty paid by the whole of Belgium. Three sugar refineries, and twenty for sugar-candy, turn out respectively 10,000 to 12,000 tons and 12,000 to 15,000 tons per annum. The manufacture of tobacco for smoking has risen to 8,400 tons of raw material imported per year; and the yearly make of cigars is 80 millions. The wool imports exceed 170,000 bales per annum, Antwerp ranking next to London and Liverpool among European markets; the Merxem wool-combing mills are among the largest of the kind.

The industries of Antwerp may some day rank as high as do her commerce and arts already.

A. B.

Self-Acting Coal Tip.

(Glaser's Annalen für Gewerbe und Bauwesen, vol. v., col. 315.)

This apparatus, designed and manufactured by the "Gutehoffnungshütte" Co., Oberhausen on Ruhr, consists of a platform carrying rails hung from trunnions in such a manner that, when a loaded truck is run on to it, the centre of gravity of the system is in front of the point of suspension. The front wheels, when they reach the end of the platform, depress levers which cause hooks to clip the front axle, and so secure the truck in position; the platform is now allowed to tilt forwards to the necessary angle (about 45°), the movement being controlled by a brake keyed on a shaft, which gears into toothed segments on the trunnions. When the truck is tilted, the end is opened and the coal is shot into a hopper, and thence by shoots into the vessel; the removal of the load alters the position of the centre of gravity, so that now it is behind the trunnions; this allows the platform to sink back into its original position, under the control of the brake as before. One of these tips is erected at Ruhrort, and works satisfactorily; the tipping is found to be entirely self-acting, there being only a few abnormally long and low trucks, by which the centre of gravity is so far back as to require the use of the hand gear provided in case of need. At Ruhrort the tip is worked by one man at the brake, six to eight men being employed in shunting; from fourteen to twenty large trucks ("Doppelwaggons") varying with the construction of truck, are discharged per hour, and this number will be increased when another siding is provided. The cost of emptying the trucks is at Ruhrort about half that on the old method of hoppers.

W. P.

Stoking Competition of the Bergischer Dampfkessel Verein.

(Mittheilungen des Verbandes der Dampfkessel Ueberwachungs-Vereine, 1879, p. 78.)

The trials were made with a boiler supplying steam to a horizontal high-pressure pumping engine of about 30 HP. indicated.

The boiler consisted of two plain cylinders, one over the other, connected by two tubes; the steam pressure averaged 4½ atmospheres; the feed was heated to 136° Fahr.; the heating surface was 242 square feet, and the grate surface was 10·76 square feet.

Fourteen competitors entered, and each fired for one day, from 7 A.M. to 7 P.M.; each man had an allowance of kindling wood, and 110 lbs. of coal to start with. The fire was drawn at night, and the ashes and clinkers weighed.

The prizes were given for the least gross weight of coal used per indicated HP. per hour; the result showed unexpected differences. The first prize was given for a consumption of 5·71 lbs.; the

worst result was 7·67 lbs., the ratio of the two being as 100 to 134.

The following is taken from the tables given in the report:—

——	First Prize.	Last.	By any Competitor.	
			Minimum.	Maximum.
Number of times fire door opened .	186	244	122	300
„ coal thrown on .	132	168	78	168
„ fire trimmed . .	45	39	17	106
„ fire broken up. .	8	28	2	28
„ clinker removed .	1	9	1	14
„ damper altered .	17	3	3	64

The report contains full tables of results, and a detailed criticism of the management of the fire. Amongst other things, a great difference was shown in the use of the damper; the best stoker began with a partially closed damper, and gradually opened it as clinker formed; at midday he thoroughly cleaned his fire and started as before. The worst man almost ignored the existence of the damper, and kept it wide open all day.

W. P.

Steam Boilers having Automatic Dampers. By M. De Bonnard.

(Resumé de la Société des Ingénieurs Civils, 1879, p. 244.)

M. Bonnard estimates that, in stoking a steam boiler every five minutes, the door is necessarily open for at least 10 per cent. of the whole time during which the boiler is at work; and he argues that, by connecting the damper with the furnace-door, so that the damper becomes closed or nearly closed whilst the door is open, and so checking the injurious in-draught of cold air, a material degree of economy can be effected. According to one arrangement, which has been in operation for some years, a door sliding horizontally, and the damper in connection with it, are moved simultaneously by turning a crank handle. Applied to an inside fire-boiler, the comparative results of twenty-four-hour trials successively, showed an increase of evaporative efficiency of 13·7 per cent. of fuel by the adoption of the automatic connection. By another arrangement, applied to hinged doors, an increase of efficiency of 14·9 per cent. was effected.

D. K. C.

Martin's Indicator for Steam Engines.

(Annales Industrielles, August 17, 1879, col. 200.)

Martin's indicator was designed for the purpose chiefly of neutralising the vibratory action caused by the percussion of the entering steam on the piston of the instrument. For this object the steam passage to the instrument is enlarged at one point, to make room for a disc-valve which takes its bearing upwards, and is pressed up by the steam at each admission against the bearing. The valve is so formed with snugs or projections, that it cannot close the passage upwards to the piston of the indicator; so that, whilst the steam is allowed free way into the indicator, the valve receives the first shock of the entering steam, and prevents its playing on the piston. When the steam is exhausted, the valve falls to its seat, and leaves the way fully open for the returning steam. By this means, whilst the whole pressure of the steam is felt by the indicator-piston, during both the steam-stroke and the return-stroke, the diagram is freed from incidental undulations; and, it is stated, diagrams taken by the Martin indicator are as regular and as exact for speeds of from four hundred to five hundred revolutions per minute, as those from the Richard indicator at two hundred revolutions per minute.

The piston of the indicator is hollow and completely closed, and is made steamtight by two circular grooves in the circumference. By means of a simple parallelogrammatic arrangement, the movements of the pencil are strictly rectilineal, and equal. The paper-drum receives its reciprocating motion from a toothed pinion gearing into a toothed wheel on the axis of the drum. As the pinion is on an axis at right angles to that of the wheel, the teeth are inclined at an angle of 45° with their axes respectively. The reciprocating movement is communicated by a cord over a small drum on the axis of the pinion, through an intermediary coiled spring.

D. K. C.

Indicated Performance of a Compound Steam Engine.

By M. Quéruel.

(Resumé de la Société des Ingénieurs Civils, p. 225.)

M. Quéruel contends that, for so many times as the initial pressure in a steam engine exceeds 4 atmospheres, and the ratio of expansion 5 volumes, there should be employed as many cylinders, in compound relation. He discredits the usually-accepted fact, that, in expansive-working engines, the steam is alternately condensed and re-evaporated in the cylinder in the course of the stroke. He, on the contrary, appeals exclusively to the

evidence of the indicator diagram; and he infers from the results of experiments with a compound vertical engine of 250 HP., steam-jacketed, based on indicator diagrams, that there is no initial condensation of steam in the first or high-pressure cylinder, and that there is only from 5 to 10 per cent. of re-evaporated steam in the second or low-pressure cylinder. So far from recognising a loss of efficiency for high ratios of expansion, he finds that the efficiency increases even up to and beyond 25 volumes of expansion. In effect, the consumption of steam per effective HP. per hour is:—

Maximum.	13·15 lbs. for 10 volumes.
Mean	11·28 „ „ 19 „
Minimum	10·05 „ „ 26¼ „

The quantity of steam consumed was calculated, not from the feed-water delivered to the boiler, but from the pressure and volume of the steam in the first cylinder, at half stroke.

The President, M. Farcot, observed that, in order to arrive at definite conclusions on the efficiency of a steam engine, the quantity of feed-water consumed should be measured, as well as the indicated quantity of steam passed through the cylinders.

D. K. C.

Automatic Variable Expansion Meyer Gear. By A. Pelissier.

(Zeitschrift des Vereines deutscher Ingenieure, vol. xxiii., p. 379.)

The Author commences by briefly enumerating the advantages of the Meyer expansion gear, remarking that with a proper choice in the proportion of parts it is possible to provide for ranges of expansion varying from nothing up to full stroke, at the same time giving wide port openings, and obtaining a very rapid cut-off. He then, with the aid of three illustrations, describes the arrangement of gear of which a number are at work.

The expansion-valve spindle is provided with a strong stud, which has of course a constant travel; a plate is carried on this stud, being free to slew round the latter. This plate has two curved slots in it, one being at each side of the central carrying stud. The cut-off valves, working on the back of the main distribution valve, have each studs secured into their backs, these studs entering the curved slots in the plate driven by the expansion-valve spindle. It will thus be evident that if this plate is made to slew round the stud carrying it, the expansion valves will be drawn nearer together, or spread farther apart, as their relative position to each other is determined by the situations of the studs in the slots in the plate carried by the stud on the expansion-valve spindle. The motion of the slewing plate is changed by allowing a stud fixed in the end of a lever carried by this slewing plate to come in contact with hardened plates in the ends of a slotted frame, supported by a couple of parallel motion bars placed

inside the steam chest, the position of this slotted frame being determined by its connection to a weighted cross-armed governor. A light spring is placed between the slewing plate and the cut-off plates, to prevent the latter flying off the back of the distribution valve when the engine is still running after steam has been shut off. D. Ha.

On Auxiliary Starting Gears. By T. RITTERHAUS.

(Civilingenieur, vol. xxv., col. 323.)

The Author remarks that although machines of this nature are in extended use in England and France, they are almost unknown in Germany. The first examples he refers to are those of Farcot, patented in 1868, and since successfully used for steering ships, revolving the turrets of ironclads, training heavy guns, and giving motion to the valve-gear of large engines, &c. He next notices an arrangement designed by Reuleaux, and exhibited in the collection of kinematic models at the Berlin Technical High School; the motion in this case, as in most of the others, is obtained by a system of differential levers. A modification of this form of gear is also illustrated, in which one of the levers is omitted, and the motion is obtained by the introduction of a parallel motion. A further example shows this gear in its simplest form, and with the least possible number of parts.

Closely allied to the last described arrangements, is the gear shown by Cramp and Sons, at the Philadelphia Exhibition, for working the link motion of a pair of marine engines, and that used by Brown Brothers and Co. on board the Bessemer. Particular interest is attached to this latter, owing to the high water-pressure at which it works, the limited room available making it necessary to have all the machinery placed in the least possible space.

Goffint's gear is then described; in the case referred to it is used in connection with a large pair of winding engines, having ordinary slide valves, driven by a Gooch link motion. As these valves were not balanced, their friction naturally became excessive, and necessitated the introduction of some mechanical means to render the handling of the engines possible. Another modification of Farcot's design is then referred to, which has been used for the steering gear in three French ironclads, a cataract being here introduced to neutralise the effect of the sudden blows received by the rudder. In order to prevent as much as possible the inconveniences produced by condensation of steam in the cylinders, the valves are so arranged as to admit steam into both ends of the cylinders when the gear is not at work. The three next modifications illustrated are by Lieutenant Jaquemier, of the French navy. In all the former arrangements the motion was produced by means of a series of levers linked together; here the same end is attained

by means of a combination of inclined planes and worm motion in the first two samples, and of a sort of differential jack-in-the-box motion in the third. The Paper concludes with a long description, illustrated by diagrams, of Brotherhood's steering gear, as applied to the "Castalia" and H.M.S. "Téméraire."

D. Ha.

The Flexible Shaft. By G. Burnham, Jun.

(Journal of the Franklin Institute, September, 1879, p. 157.)

The flexible shaft is made up of a core and a case, and fittings for joining them; so that rotary motion communicated to one end of the shaft is transmitted to the other end. The core is composed of a series of concentric steel wire coils wound hard on each other, the direction of the coils being alternately right-hand and left-hand. The direction of the outermost coil is such that the coil tends to contract by the stress, the shaft running one way only. The case is made of a hollow coil of square wire, having a slight groove on the outer side to prevent the leather sheathing applied to it from slipping. The diameter of the case, inside, is slightly larger than that of the coil. The ends are fitted with iron ferrules to receive the driving pulley and the hand-piece, which carries the working tool. The principal employment for the flexible shaft has been the drilling of metals, at various angles with the axis of the driving apparatus. But its uses are various: for instance, in grinding and polishing metal work, cleaning the sand from castings with wire brushes, stone working, horse and cattle brushing, and boot blacking. The flexibility of the coil shaft is instanced in the case of a shaft having a $\frac{5}{8}$-inch core, and 6 feet in length, which can be worked when bent so as to form a complete circle, or through an angle of 360°.

D. K. C.

Eighty-Ton Steam Hammer at St. Chamond Works.[1]

(Bulletin du Comité des Forges de France, 1879, pp. 273 and 301.)

In the colossal steam hammer erected by the Fives-Lille Co. at the St. Chamond Iron and Steel Works (in the department of Loire, France), the tup, piston-rod, and piston make up a falling weight of 80 tons (correctly 80 tonnes French = $78\frac{3}{4}$ tons English), with a stroke of 16 feet 5 inches. The piston is of cast steel; and the piston-rod, also of steel, is $26\frac{1}{4}$ feet long, and $13\frac{3}{4}$ inches diameter. The cylinder, $19\frac{1}{2}$ feet high, $74\frac{7}{8}$ inches diameter, and $2\frac{3}{8}$ inches thick, is cast in two pieces; it weighs 25 tons itself, and with the

[1] An account of a similar hammer at Creusot is given in "Engineering," October 11, 1878, p. 289.

entablature on which it stands 48 tons. The standards each weigh 135 tons, and each is made in two halves, hooped and bolted together, between which are fixed the guides for the tup; the cross ties at top are a pair of armour plates $4\frac{3}{4}$ inches thick, let into the standards; the tie-plates, bolts, hoops, valve-gear and valves, amount to 80 tons. The cast-iron sole-plates of the standards weigh together 122 tons; they are braced together, and secured by 6-inch holding-down bolts. The anvil block, weighing 500 tons, is built up of five pieces, secured together by lugs and hoops, the top piece alone weighing 110 tons; the whole rests on a timber bed, which is formed of oak beams, $15\frac{3}{4}$ inches square, set on end, and keyed and bound together by strong iron hoops. The weight of metal in the hammer and anvil altogether amounts to 1,100 tons.

Around the hammer are ranged four 120-ton swing cranes, constructed of mild steel plates, the top pivots of the crane posts being held in a massive framing of plate-iron girders, weighing 175 tons, erected on a masonry foundation of more than 6,000 tons. Each crane is worked by two steam cylinders, of 35 HP., by which the forging can be raised or lowered, traversed radially along the jib, swung by the jib, or slewed round without swinging.

Steam is supplied to the hammer and cranes by twelve boilers.

A. B.

The Victor Turbine.

(Engineering and Mining Journal, New York, vol. xxviii., p. 145.)

A new form of turbine is described, which consists of an outer case formed with a bridge tree and wood step, supporting the wheel in position; this case is one casting, and is bored to receive the cylindrical register-gate revolving within it, and which is so fitted as to ensure the wheel's setting being truly level. The register-gate, which also is cast in one piece, is moved by means of a segment and pinion, and its use enables the supply of water to the wheel to be so regulated, that an equal and uniform delivery may be ensured, without changing the direction of the current, the relative angle of the stream at the face of the bucket, or in any way checking the velocity of the water admitted to the wheel. The construction of the top of the wheel has certain special features, which also add to the general efficiency; the wheel itself receives the water from the outside and discharges it downward and upward, the lines of discharge occupying the entire diameter of the lower portion of the wheel, except the space occupied by the lower end of the shaft. Great stress is laid upon the small number of parts in this turbine, considered in relation to its efficiency; and it is stated, that an 8-inch wheel of this construction will develop 10 HP. under a head of about 21 feet. The Paper is illustrated with perspective drawings.

E. S.

Fleischer's Hydromotor Propeller.

(Hamburgische Börsen Halle, 31 July, 1879.)

Attempts have several times been made to propel vessels by hydraulic reaction instead of by screws or paddle-wheels, and it appears that, up to the present time, about seven vessels have been constructed on this principle, four in England, one in Belgium, and two in Germany. In 1853, John Ruthven, the reinventor of the system, built the "Enterprise," but this steamer was a failure and was converted into a sailing vessel. In the same year Seydell built the "Albert," in Stettin, which boat ran successfully on the Oder for ten years. About 1860, the steamer "Seraing No. 2," was built by Cockerill, who fulfilled a contract that her speed and fuel consumption should be as good as that of the sister ship "Seraing No. 1," which was fitted with feathering paddles. In 1863 the British Admiralty applied the principle to the "Jackdaw," but she proved a complete failure. In 1865, the "Nautilus" was built, and ran at a speed of 10 knots an hour on the Thames with great success. In the same year the ironclad "Waterwitch" was constructed and proved successful. Finally, the "Rival" was built for the German navy in 1870, but a failure was the result, partly owing to the fact that she drew a foot more water than was intended.

The principle of reaction vessels consists in taking in water through holes in the bottom, and forcing it out through nozzles placed about midships near the water line, the propelling force being dependent on the quantity and speed of the water pumped. The object of the hydromotor is to substitute a simpler and lighter mechanism for the engine and centrifugal pump usually employed. The apparatus operates by direct pressure of the steam on the water, and consists essentially of a boiler, two vertical water cylinders, a surface condenser, and a donkey air-pump. The water cylinders work alternately, the valves being actuated by floats; at the end of the stroke the steam passes into the condenser, and the vacuum thus formed enables the cylinders to be recharged. A considerable degree of expansion is used, a layer of oil being kept on the water to prevent undue condensation. The apparatus has been fitted to the "Pellworm" with good results; experiments made with this steamer show that the effective work done in propelling the ship is about 40 per cent. of that indicated by the steam in the cylinders when running at 10 knots per hour.

W. P.

NOTE.—The hydromotor seems to differ from those pumps of which the pulsometer is the best known type, principally in the addition of a surface condenser and air-pump, and in the use of expansion; the diagrams show a cut-off at ¼ of the stroke, and about 8½ inches vacuum.

Inquiry into the Possibility of the Use of Wind Power for Irrigation in India.

(Professional Papers on Indian Engineering, July, 1879.)

Mr. F. B. Thuber, of New York, wrote to Colonel Brownlow, R.E., the officiating chief engineer of the North-West Provinces Irrigation Works, inviting attention to the desirability of using windmills as a means of raising water; Colonel Brownlow replied that he considered the wind in India to be too uncertain and variable, but desired his assistant, Mr. Nelson, to report on the subject; which report is published with Colonel Brownlow's note. Mr. Nelson deduces from Smeaton's treatise a minimum velocity of 4½ feet per second, or a little more than 3 miles an hour, as the least which will move the arms of a windmill with effect, and appends to his report a table abstracted from the monthly returns of the meteorological reporter. A study of the table shows that—

(i.) At Roorkee the average velocity of the wind during a period of thirty-seven months, from November 1871 to November 1874, exceeded 3 miles an hour during ten months, and 4 miles an hour during two months.

(ii.) At Bareilly, 3 miles an hour was exceeded during twenty months, and 4 miles during seven months, out of thirty-seven.

(iii.) At Agra, 3 miles an hour was exceeded during twenty-six, and 4 miles an hour during sixteen months, out of thirty-seven.

(iv.) At Lucknow, 3 miles an hour was exceeded during eighteen months, and 4 miles an hour during seven months.

(v.) At Benares, 3 miles an hour was exceeded during twenty-two months, and 4 miles during thirteen months, out of thirty-seven.

Save in very exceptional circumstances, irrigation is only required during November, December, January, and February for the Rabi (cold weather) crops, and during April, May, and June for the Kharif (hot weather) crops; the area irrigated in Rabi is about four times that irrigated in Kharif.

The anemometrical results for the five years 1871 to 1875 (inclusive) show that February is the most windy Rabi month, but yet the wind was so often below 3 miles an hour, that Mr. Nelson considers it may safely be said that windmills would not work.

For the purposes of Kharif irrigation it would appear that windmills are feasible, but during April, May, and June violent sandstorms, capable of throwing down large trees, are of frequent occurrence, and any mill to be worked during those months must needs be of great strength and very expensive.

Mr. Nelson's report is followed by a report on the same subject from Mr. H. F. Blanford, meteorological reporter to the Government of India, in which the mean hourly movement of the wind at Agra is tabulated. Mr. Blanford remarks that the result shows that, on an average, there are several hours during the day in

which the velocity of the wind at Agra is considerably above the requisite minimum deduced from Smeaton's estimate, although the mean of the twenty-four hours in certain months is below that minimum, and it may still, therefore, be a question whether at stations such as Agra windmills might not be used with advantage.

The above reports are accompanied by extensive extracts from Smeaton's experimental papers on the subject, as edited by Tredgold. W. P.

Rope Connections for Mining Cages. By F. BAUMAN.

(Zeitschrift des Vereines deutscher Ingenieure, vol. xxiii., part 9, Sept. 1879.)

This Paper is illustrated by diagrams which appeared in the preceding number of the "Zeitschrift," showing many of the ordinary modes of connecting winding ropes with winding cages. In the first three figures given the attachment is made by serving the rope over with wire, or uniting the two parts by rings or clamp clips held together by bolts and nuts. Exceedingly light thimbles are shown in all these examples; and it is stated that the improved form, introduced by Messrs. Felton and Guilleaume, was designed to obviate the damage resulting to the rope from their use. This arrangement consists in using a solid pear-shaped block, round which the rope is laid, the end being made fast to the standing part by a screwed clip. Two light plates, rather larger than the block, are riveted together, with the block between them, holding the rope firmly in position. The weight of the cage is borne by a shackle carried by a pin passing through the centre of the block. The Author then describes some trials carried out with an improved form of attachment, consisting of a hollow truncated cone through which the rope passes, and is held in position by three or more wedge pieces having grooves cut on their insides corresponding to the twist of the rope. The first trial was made with a seven-strand wire rope 1·1 inch in diameter, each wire having a diameter of 0·1 inch. The weight of the cage was 8 metric tons, and after it had been raised several times, the coupling was undone, and the rope was carefully cleaned; it was found impossible to recognise the place where the coupling had been made fast. The second trial was made with a five-strand wire rope 0·74 inch diameter, containing thirty wires, each 0·1 inch diameter. The cage was loaded with weights representing two, four, six, and eight full tubs, each weighing 1760 lbs. On the total weight being increased to 75 metric tons, the rope broke at a distance of 9·84 feet from the coupling. On the coupling being taken off, it was in this case also impossible to see on the rope where it had taken hold. On the completion of these trials, a rope so fitted was set to work at the No. 1 pit, in the Friederichsthal mine, where it has given every satisfaction.

A further improvement has been made in hingeing the outer box together longitudinally, so that the box can only be closed when the wedge pieces are in place, if the ridges on the wedge pieces are in their proper places with regard to the grooves formed by the strands of the rope. The core of the rope can never be injured when this arrangement is applied, and this advantage is made use of when it is wished to maintain electrical communication with the engine room and the cages when in motion. The wires are carried through the core, and pass out of the end of the winding rope which descends for a short distance beyond the coupling into the cage.

D. Ha.

On Safety Cages for Mines. By Dr. F. Nitzsch.

(Abhandlungen des Vereins zur Beförderung des Gewerbfleisses, 1879, p. 345.)

After investigating the varying strains to which a winding rope is subject, the Author shows, by numerical examples, that, with two engines coupled at right angles to a cylindrical winding drum, the dynamic strain while winding may, when the velocity is being accelerated, considerably exceed the static strain due to the load alone, but that the greatest danger of breakage arises from too suddenly checking the speed when lowering a load.

The distance a cage and load of the weight q, moving downwards with the velocity v, falls, after breakage of the rope, is

$$s = \frac{q}{p} \cdot \frac{v^2}{2\,g},$$

where p represents a constant retarding force applied within the cage by the safety gear. Amongst a great number of inventions, the Author has only met one which professedly fulfils the condition, that the retarding force p should not be able to become so great as to exceed the strength of the cage. If the rope part above the surface, it falls like a fluid stream of iron on the cage. In order to stand the blow, the roof should be made strong enough to bear a static load of about three times the weight of the rope, and the safety gear has to carry an extra load of once the weight of the rope.

Detailed descriptions are given of seventy-five different safety cages. Nearly all rely on the principle of the pull on the rope, keeping the clipping gear free from the guides by compressing springs or other means. In case of the rope breaking, the springs fly out and the retarding force is applied. In many of the older designs, bolts, pawls, or knife-edges are employed; but these tear down the woodwork by checking the speed too suddenly. The later systems are more of the nature of friction brakes; but the Author considers that, at present, the only really reliable safety cage is Hoppe's, as used in several mines in Upper Silesia. This

apparatus has, in several cases of failure of the winding rope, brought the cage quietly to rest without damage to passengers or material. Several inventors substitute suspended weights for springs within the cage. These are useless, as the cage itself falls at the same speed as the weights.

The Paper is illustrated by twenty-three sheets of drawings of the appliances described.

W: P.

Oscillating and Portable Melting Furnace. By R. Grimshaw.

(Journal of the Franklin Institute, July 1879, p. 48.)

The ordinary method of using crucibles for melting and pouring steel and brass is extremely wasteful, both as regards the fuel and the crucibles themselves. The Author describes an oscillating and portable melting furnace invented by A. Piat (France), which diminishes this waste. The furnace consists of a square case, made from boiler plate and lined with refractory materials. The pot nearly touches the sides, while the fuel fills the corners. An iron band is clamped round the case, and carries two trunnions, arranged at such a height as that the furnace may be easily tipped when the pot is nearly full of metal. These trunnions serve for lifting and carrying the furnace, which has a pouring hole and spout arranged in front near the top, opposite to the spout. At the back is an opening by which, when the furnace is in position, the connection is made with the chimney flue. The top of the furnace is covered with a movable tile. The crucible, when in place, is supported on a block of refractory material resting on the grate, and is wedged tight (by means of a fire-clay block), so that its upper part rests against the spout. After the first heat or so, these pieces become united to the pot. The entire arrangement rests on brick supports, and receives a blast pipe below, if a blast is employed, the grate being cleaned every two or three heats by tipping and slicing from below. These furnaces are made to melt up to 600 lbs. of brass; but for steel, and pieces over 75 lbs. weight, it is proposed to arrange a special furnace, besides other smaller ones, to receive their contents and carry them to the place of pouring. After the melting is completed, the furnace may be conveniently placed in trunnion holes, arranged upon a small truck designed to carry it from place to place, the pouring being easily accomplished by a simple mechanical device attached to the framework.

A section of the furnace, crucible, grate, and flues, arranged in working order, and a view of the furnace mounted on its carriage, accompany the Paper.

E. S.

Rebuilding of a Blast Furnace Stack without blowing out.

By Hr. Burgess.

(Oesterreichische Zeitschrift für Berg- und Huttenweisen, xxvii. p. 499.)

In the early part of 1878, No. 1 furnace, at the works of the Bochum Verein, was found to be extensively damaged in the upper part of the stack, from the action of the gases, and it was decided to remove the lining nearly down to the level of the boshes, and replace it with a new one of small bricks. The furnace, which is 72 feet high, 21 feet diameter in the boshes, and had been blowing for two years, was not put out of blast, as the hearth and boshes were in good condition, but would probably have required replacing if they had been allowed to grow cold; and also the delay would have been considerably greater than actually took place, the repairs having been executed in twelve days.

At the time of the stoppage the furnace was on Bessemer pig-iron, and, in order to expedite the cooling, the burden on the last day was reduced to one containing only 25 per cent. of iron, the other materials being so proportioned as to give a tolerably fusible slag. The final eight charges consisted of $2\frac{3}{4}$ tons of coke and 9 tons of grey slags. The furnace was then allowed to work down until a depth of 49 feet below the shaft was emptied. At the last cast very little iron was obtained, but it was accompanied by a large quantity of black and glassy slag.

About 10 tons of grey metal slags which fall to powder when cooled were next charged upon the top of the column of materials in the shaft. This was in places at a low red heat with the coke glowing brightly, and the charging bell was lowered on to the top of it. Eight holes were then cut through the walls of the furnace, with a view of expediting the cooling by the influx of cold air. The effect produced was, however, the reverse, as the combustion of the coke became more active when the air was admitted; the holes were therefore closed up again, and a further quantity of powdered slags was introduced, until the covering was from 1 to 2 feet thick, when the temperature at the tunnel head became quite bearable.

A sheet-iron funnel with a long tube 15 inches in diameter was next introduced into the empty space, to one end of which were three Korting's exhausters, each supplied with steam by three $\frac{5}{8}$-inch jets, for the purpose of removing the furnace gas and supplying fresh air, an arrangement that was perfectly successful in practice. The damaged brickwork, as it was broken away, was removed by five windlasses at the furnace top, each worked by four men, one of whom filled the materials lifted into barrows and removed them to the lift. From eight to ten men were employed in the furnace, and they did not experience any inconvenience or discomfort from heat, or bad air, this part of the work being preferred to that at the furnace top. From $3\frac{1}{2}$ to $6\frac{1}{2}$ feet in height of the lining was

removed per shift. Below 8 feet from the furnace top the men worked upon a suspended staging, which was lowered progressively; subsequently, two holes, of about 10 square feet area, were made in the furnace wall, and two plates of the iron jacket were removed at the depth of 49 feet from the top, so that the materials could be got rid of without the necessity of lifting them through the whole height of the furnace. The new lining was carried out with small bricks in the ordinary way of walling, and was finished in ten shifts.

In filling the furnace when the repairs were completed, the bell was lifted about 7 feet at a time, and the space charged from baskets by hand, until the column was within 20 feet of the top, when it was replaced in its proper position and the ordinary method of charging from barrows was resumed. When the blast was turned on, and the smelting recommenced, the charges went down regularly without any sign of scaffolding. In eight days the furnace had resumed the full make of 50 to 60 tons per shift.[1]

The damage done to the lining by the gases was first perceived at a depth of 20 feet from the top, where the bricks became rotten and brittle, and were scoured out by the descending charges into large holes, one of which, at 20 feet depth, was 6½ feet across. Lower down, the section of the stack was fairly well preserved, but the bricks were completely rotten except for an outside portion of from 2½ to 4 inches, which remained sound. The damaged portions were covered with innumerable circumferential cracks, as though they had been split by forces acting from the inside. The colour was bluish grey, and the interior cavities were filled with concretionary substances varying from the size of a pea to that of a bean.

The furnace is still in blast and working satisfactorily, a period of fifteen months having elapsed since the repairs were made.

H. B.

The Metallurgy of Zinc in the United States. By W. STRECKER.

(Berg- und hüttenmännisches Jahrbuch, Leoben, vol. xxvii., p. 282.)

This report contains the results of a personal inspection made by the Reporter of nine of the thirteen zinc works in the United States.

The ores treated are chiefly Willemite red zinc ore (oxide of zinc), Franklinite from Sterling, New Jersey, blende from Friedensville, Pennsylvania, and calamine from eastern Missouri and southwestern Wisconsin. Of these, Franklinite is the least valuable, on account of the high proportion of iron to zinc, but is employed

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[1] 500 to 600 tons in original.

in the direct production of zinc white, a process which was adopted for some time before the introduction of the reduction process into the country.

The chief seats of the manufacture are at Newark, New Jersey, Lasalle, Illinois, Lehigh, Pennsylvania, and St. Louis and Carondelet, Missouri.

The retorts and fire-bricks used in the manufacture are produced from clays raised at Woodbridge and Ambry, in New Jersey, and Cheltenham, near St. Louis, in Missouri. In one case, at the Bergen Port Zinc Works, worn-out Bessemer tuyere bricks are used as a stiffening material for the mass from which the retorts are made, and are said to answer the purpose admirably.

The calcination of the calamine ores is effected in kilns, and that of blende in reverberatory furnaces. At the Matthiessen and Hegeler Company's Works at Lasalle, Illinois, two special forms of the latter are employed. The first is a block of brickwork, of cubic form, about 14·76 feet in the side, divided internally into five parallel sections, only 2·95 feet wide, but extending the whole length and height of the furnace. Each compartment contains eight parallel beds one over the other, not quite of the same length as the furnace, a space being left at the front and back ends alternately; the flame which enters below is therefore obliged to traverse the whole length of the beds backwards and forwards before reaching the top, the ore moving in the opposite direction or from above downwards. Fireplaces with their ores parallel to the long dividing walls are in a separate block at each end, the flame being introduced by special flues. The yield of this furnace is 36 cwt. daily, the ore requiring twenty-four hours to be completely roasted. In the second system of calcining at the same works, the furnaces are 52½ to 59 feet long and 15 feet broad, also with eight working beds; but these are not plane surfaces, being broken into ridgelines like house roofs, the parts being so arranged that the ridge of one is below the furrow of the surfaces on the bed next above. In this way the whole block is divided into numerous cells of a trapeziform section. At the lowest point, between each pair of inclined surfaces, the bed is perforated by a round hole, through which the partly-roasted ore is passed to the next division below. The interior is reached through working holes at corresponding levels in the long side of the wall. The firing is arranged in separate fireplaces at the ends as in the first system.

The reduction of the calcined ores is, in all cases, performed in furnaces of the Belgian pattern, anthracite being generally used as fuel. This is either burnt directly, or in gas producers with or without regenerators. The only example of the former class of furnace is at the Illinois Zinc Company's Works at Lasalle, who have a Siemens' double gas furnace, with two hundred and forty retorts in use. The largest furnace is one at Matthiessen and Hegeler's works, which has four hundred and eight retorts, fired by gas without using the regenerative system. The large furnace

produces from 5 to 6 tons of zinc daily, and the smaller ones in proportion. This furnace and another, containing 136 retorts, are served by twelve gas producers, contained in a block of masonry 23 feet long, 14 feet 9 inches broad, and 11 feet 6 inches high. The inclosed firegrates are made with firebricks instead of iron bars, as the latter, from the ashy character of the coal, would be rapidly destroyed by the formation of slag. The retorts in these furnaces are arranged in five rows; those in the upper row are of rectangular section, and two or three times the capacity of the cylindrical ores in the lower rows. The former are divided longitudinally into sections, each of which contains four rows of seven, or twenty-eight cylindrical, and six prismatic retorts. The latter, which are exposed to the highest temperature, are charged with the most difficultly reducible, those of the second and third row from above with calamine, while the bottom row is reserved for zinc fume skimmings and other rich intermediate products. The whole production of zinc in the United States in 1875 was 14,763 tons, but it has considerably increased since that time. About 6,000 tons of zinc white were also made direct from the ore according to Wetherill's process, which the Author considers to be equally well adapted for use in Europe, as it can be successfully applied in some cases with inferior materials, blende and coke being adopted for the purpose at some places in America, as well as with the purer Franklinite of New Jersey, and anthracite of Pennsylvania, originally used in the works of the eastern States. The average market price of zinc in January 1879 was £23 16s. per ton, but a very fine variety made from blende by the Bergen Port Zinc Company realised double that price. This is exported to Hamburg for use in Europe, where it is melted with Lake Superior copper into brass of very high quality, to be used in the production of metallic cartridge cases.

The average consumption of coal in the production of 1 ton of zinc in different works varies from 5·6 to 7·4 tons, of which from 4·5 to 5·5 tons are burnt in the fireplaces of the calciners and reducing furnaces, and 1·2 to 1·9 ton are added to the charge in the retorts. The larger of the above quantities correspond to the treatment of a blende containing a considerable quantity of iron. Of the total quantity of zinc in the roasted ore, the amount recovered is from

Blende	71 to 73 per cent.
Calamine	73·5 to 80 „
Silicates	71 to 80 „

The manufacture of zinc white by Wetherill's process is fully described by the Author. This consists in exposing to a moderate heat finely crushed ore, which may be either the mixed Franklinite and silicates of New Jersey, calamine, or, in some cases, roasted blende, mixed with limestone and coal in a layer about 6 inches deep, upon the bed of a muffle-shaped furnace, formed of a cast-iron plate perforated with numerous holes, through which air at

a low pressure is forced by a fan blower. The zinc oxide in the ore is reduced by the burning coal, and rises in the state of vapour, together with the other furnace gases, consisting chiefly of carbonic acid; but when they have cooled down somewhat, the metal is re-oxidised, the carbonic acid being at the same time reduced to carbonic oxide. The zinc oxide, in the form of a fine white powder, is carried through a system of chambers in pipes to which coarse cotton cloth sacks are attached; these act as filters, the permanent gaseous products finding their way into the atmosphere through the meshes of the cloth. The residues from the treatment of the New Jersey Franklinite ores by this process contain about 25 per cent. of iron and 14 of manganese, and were formerly smelted for Spiegeleisen at the Newark Works, the oyster shells from the New York eating-houses being used as flux; but at the time of the Author's visit this part of the process had been abandoned, and the residues were allowed to accumulate in great heaps about the works.

H. B.

On the Present and Prospective Conditions of the Petroleum Fields of Pennsylvania. By H. E. Wrigley.

(Engineering and Mining Journal, New York, August 2, 1879.)

It is an admitted fact that the conditions governing the area and indicating the exact situation of the oil-producing territory in Pennsylvania are still undefined, or at least uncertain; in other words, no known law has yet been discovered by which Nature's arrangement of sand-rocks, crevices, or cavities can be interpreted as a sure guide to the well-sinkers; and all the great oil spots or areas of the region have universally been discovered by the so-called "wild cats," or men who put down wells in out-of-the-way places on mere chance, or on some theory or fancy of their own. Where one succeeds hundreds fail; but if the "wild cat" proves a small well, or if even a few feet only of good sand are found, it is enough to give the driller a clue, and by sinking wells east and west of it he can readily determine in which direction the sand thickens, and after that the work of defining the oil-spot proceeds rapidly.

Geology indicates, however, that the area of the Pennsylvania oil regions is limited. The two questions of interest are therefore: 1st. How much oil *can* be taken out? 2nd. How much oil *has* been already taken? The diagram of the life of wells from 1859 to 1875, given in vol. J. of the Second Geological Survey of Pennsylvania, shows the average life of all the wells during that period, or the length of time during which they continued to produce oil, to have been two and a half years; and there is no known instance of an old pumped-out well being made to produce again to any

extent worthy of note, although there have been some special isolated cases of wells producing small amounts for nine, or even twelve years.

In the Bradford or northern oil-field, lying north-east of Titusville, the wells may show a somewhat longer average duration, but there the oil is found under entirely different conditions from those in the territory further south, the sand-rock being of a much closer character than in the old pebble-rock, and appearing not to be essential (as it is in the lower country) to the discovery of oil, which about Bradford is often found in the slate, and contained in crevices of the latter rock, which seem to be the real depositories of the oil, and often require to be broken into by means of torpedoes. In this northern field the sand-rock serves only as a guide to the top of the slate cap or cover, which has kept the gas from reaching the surface and has condensed it into oil.

The great Huron shale is generally accepted as the mother-rock of Pennsylvania petroleum; and the western boundary line of the oil region may be considered to be settled and defined beyond all question, as also the line which determines the limit between light and heavy oils; but the line which on the map accompanying this Paper is called the "extreme eastern line of development," simply shows to what extent wells have been sunk on that side, and marks also the boundary between oil and gas wells. The Author supposes that where the crevices in the shale or oil-bearing rock extended to the surface, the oil escaped long ago in the form of gas, and this enabled him to mark what he considers will prove to be the extreme eastern limit of the oil-bearing strata by a line which forms the axis of the neighbouring (or fifth) coal basin. The area contained between the eastern and western "lines of development" of producing territory amounts to nearly 2,450 square miles, of which 1,620 correspond to light and 830 to heavy oil territory, but the total actual producing area is only 55 square miles.

More than twenty-seven thousand wells have been drilled within this light-oil territory, of which twenty-three thousand five hundred are within the ascertained oil region, and the remainder are scattered dry "wild-cat" wells, so that the yet unworked light-oil producing area has been at least fairly tested.

The total production of the Pennsylvania oil regions, exclusive of the Bradford district, has been, in round numbers, one hundred and twenty million barrels; and judging from the general average result per square mile, there remain to be taken out within the light-oil territory, as it is usually defined, less than thirty-five million barrels.

Beyond the southern limit to this region, the sand-rocks dip from the north-west to the south-east, and the wells grow much deeper until the oil lies at such a depth that there are only gas-wells, as at Leechburg and Saxonburg. The southern limit for oil wells is therefore taken on a line where the sand-rock reaches a depth of 2,500 feet, which limit is called the "line of temperature." Few people are aware of the force with which the gas

comes from below. At the Newton gas well, near Titusville, seven 2-inch tubes were attached to the casing; six of them being left open, the seventh registered a pressure of 75 lbs. to the square inch.

At the extreme northern end of the Pennsylvania territory lies what is called the northern or Bradford oil-field, covering an area of 210 square miles, which has already produced six million, and may produce a further six million barrels; and there is, lastly, lying between what has been defined as the "extreme eastern line of development" and the line which forms the axis of the neighbouring (fifth) coal-basin, a new undeveloped oil region, covering an area of about 720 miles of average production, which the Author believes may produce thirty-five million five hundred thousand barrels.

Recapitulation.	No. of Barrels of Light Oil.
2,450 square miles of old territory, exclusive of Bradford, have produced, so far, in round numbers . .	120,000,000
210 square miles of territory at Bradford, or the northern oil-field, have produced about	6,000,000
Total already produced	126,000,000
Prospective Production.	
Allowing one-third of past production in the old territory, there remain	35,000,000
Allowing Bradford region to yield double	6,000,000
Taking the new undeveloped territory at 720 square miles, its proportionate promise of production, compared with the actual output of the old territory of 2,450 square miles, will be	35,500,000
Estimate of total future production . .	76,500,000

To this must be added the last pumpings of old wells, which cannot well be estimated, but which would not add a serious amount.

O. C. D. R.

The Sulphur Deposits in Iceland. By W. J. Gascoyne.

(Engineering and Mining Journal, New York, August 9, 1879.)

There are two or three deposits, scattered over an area of 25 or 30 square miles, but the principal mines are at Krisuvik Namar, in the south-western part of the island.

The ground is covered to a considerable depth by a blue clay, apparently formed by the decomposition of the lava of which the hills consist. This clay is perceptibly hot at the surface, and at a depth of 2 or 3 inches sufficiently so to scald the hand. Jets of steam, or *soffioni*, burst from the ground in every direction, and form in many places large pools of hot water and boiling mud—

springs which are often found to contain considerable quantities of boracic acid, and, wherever the temperature is high, the surface of the ground is, at these points, covered with a coating of pure sulphur, the earth below the surface consisting of a yellowish-white clay mixed with sulphur.

At the Brennisteinsfjall (Sulphur mountains), on a plateau to the east of Krisuvik Namar, the deposits are of a totally different character. Here a deposit of extremely pure sulphur is found, extending for some distance under a bed of lava. The surface of the lava is broken by little pits, or craters, 3 or 4 feet deep, and on clearing away the loose stones and moss at the bottom of these the sulphur is met with, lying in separate layers, singularly pure, and not mixed with the blue and white clays which also occur here. Two average samples of this ore, in a moist state, gave on analysis, respectively, 72·73, and 64·41 per cent. of sulphur, and two other dry samples gave 91·80 and 92·17 per cent. Samples from the deposits first described gave, respectively, 76·96, 79·50, and 83·26 per cent. of sulphur.

The sulphur is perfectly free from arsenic. It is separated from the ores at the mines by carbon disulphide, the heat of the boiling springs being utilised for solution and distillation. It has been observed that regions apparently exhausted become again re-sulphurised, so that the stores of sulphur are practically inexhaustible.

The blue clay which covers the whole surface of the ground around the sulphur deposits at Krisuvik Namar, contains about 3 per cent. of copper; there is also a large quantity of pink or purple clay, with malachite distributed through it, which is found to contain from 9 to 11·56 per cent. of copper, and in one of the hills covered by the sulphur deposit, masses of malachite and of bluish-black sulphide of copper are found, which have been proved by analysis to contain respectively 42·90 and 52·65 per cent. of copper.

O. C. D. R.

The Corrosion of Wrought and Cast Iron under the joint action of Fatty Matters and of Steam. By A. Mercier.

(Annales des Mines, 1879, p. 234.)

The formation of the more or less hard lumps that are removed occasionally from the cylinders of steam engines is generally attributed to the use of acid oils for lubrication; but the Author has found that fatty oils, even if perfectly neutral, have a strongly corrosive action on iron, in the presence of steam.

In one case, steam at the pressure of the atmosphere was led into a flask filled with iron turnings, which had been steeped in colza oil, rendered neutral by previous treatment with carbonate of soda. From the apparatus thus arranged, hydrogen was slowly and continuously disengaged, showing that, at a temperature of

only 100° C. (212° F.) fatty matters, not at all acid or rancid, are capable of decomposing water in the presence of iron, forming oleate of protoxide of iron, glycerine, and hydrogen.

When the same experiment was repeated with iron turnings free from grease, no hydrogen was evolved.

In an engine supplied with steam from boilers fed with hard water, the hollows of the piston were found to be filled with a hard substance, consisting of grease mixed with oleate of lime, and with unaltered carbonate of lime that had been carried in by the steam. The mass contained no iron, the carbonate of lime having completely preserved the metal from corrosion.

In another instance, in which lime had not been carried into the engine by the steam, the slide valve was much corroded, and portions of the deposit detached from it contained—

	Per Cent.
Unaltered oil	2·60
Peroxide of iron	91·55
Oleic acid	5·60
Loss	0·25
	100·00

Similar corrosions and incrustations have been noticed in the working parts of other engines, both fixed and locomotive, and their occurrence led the Author to make the following experiment. A bucket filled with iron turnings, steeped in colza oil that had been previously neutralised, was placed for eight days in a reservoir containing high-pressure steam. The turnings when removed were found to be much corroded, and the bucket contained about a pint of dark brown oil, very thick, scarcely fluid, and having a smell like that given off in treating iron with an acid. The oil was entirely soluble in ether, and contained 7 per cent. of protoxide of iron. Exposed to the air it oxidised rapidly depositing peroxide of iron. Again placed in contact with iron, it attacked this, and regained its previous state of saturation.

This explains the large proportion of uncombined peroxide that the deposits found in the cylinders and steam chests of engines commonly contain; and the formation of heavy oleate of iron accounts also for much of the corrosion and pitting of the plates of boilers to which grease from any source gains access.

In locomotives, for instance, the steam is generally taken off through a sliding regulator in the upper part of the boiler; the oil used to lubricate this becomes charged with iron and heavier than water, and thus sinks to the bottom of the boiler and attacks the plates, if the feed water used is very pure. In other cases, however, these are protected from corrosion by the previous deposit no them of a calcareous scale.

The use of mineral oils, thickened if necessary with wax or paraffin, for the lubrication of the parts of engines working in steam, would be no doubt a good mode of checking corrosion.

W. H.

Note on the Wear of an Iron Rail. By W. E. C. Coxe.

(Transactions of the American Institute of Mining Engineers, May 1879.)

The flange rail in question was made at the Philadelphia and Reading Rolling Mill in 1870, and was in use in the track of the Philadelphia and Reading Railroad from that year until 1878, in which time it had carried 67,000,000 gross tons of freight, passengers, cars, and engines. In these nine years of service the tread of the rail has worn down $\frac{3}{16}$ inch. Other rails of the same make have given equally good results.

The heads were made from puddled bars, piled, reheated, and rolled into bars $4\frac{1}{2}$ and 3 inches wide by 1 inch thick, which were again piled, and rolled into slabs 9 inches wide and 2 inches thick. One of these slabs formed the top of the rail pile, which was 9 inches square. The remainder of the pile was made up of bars rolled from two-thirds old rails and one-third puddled iron.

The composition of the metal forming the head of the worn rail was as follows:—

	Per Cent.
Phosphorus	0·422
Carbon	0·027
Silicon	0·392
Sulphur	0·032
Manganese	0·164
Iron	98·963
	100·000

Its tensile strength was 63,000 lbs. per square inch.

W. H.

Classification of Steels, by the Société Cockerill.

(Annales Industrielles, August 31, 1879, col. 266.)

The Société Cockerill, of Seraing, Belgium, arrange their steels into four classes:

1st Class. Extra mild steels.—Carbon, 0·05 to 0·20 per cent.; tensile strength, 25 to 32 tons per square inch; extension, 20 to 27 per cent., in 8 inches of length. These steels weld, and do not temper. Used for boiler-plates, ship-plates, girder-plates, nails, wire, &c.

2nd Class. Mild steel.—Carbon, 0·20 to 0·35 per cent. Tensile strength, 32 to 38 tons per square inch. Extension, 15 to 20 per cent. Scarcely weldable, and hardens little. Used for railway axles, tires, rails, guns, and other pieces exposed to heavy strains.

3rd Class. Hard steel.—Carbon, 0·35 to 0·50 per cent. Tensile strength, 38 to 46 tons per square inch. Extension, 15 to 20 per cent. Do not weld, but may be tempered. Used for rails, special

tires, springs, guide-bars of steam engines, pieces subject to friction, spindles, hammers, pumpers.

4th Class. Extra hard steel.—Carbon, 0·50 to 0·65 per cent. Tensile strength, 46 to 51 tons per square inch. Extension, 5 to 10 per cent. Do not weld, but may be strongly tempered. Used for delicate springs, files, saws, and various cutting tools.

D. K. C.

On the Use of Determining Slag Densities in Smelting.

By T. Macfarlane.

(Transactions of the American Institute of Mining Engineers, May 1879.)

In smelting copper, lead, and silver ores, it is scarcely possible, in every case, to make analyses of the various parcels of ore, with the view of combining these and the fluxes so accurately as to yield, in the furnace, slags of exactly the most favourable composition; and to make analyses of the slags, while the smelting process is going on, is even more impracticable, on account of the time that these would take; while it is not always possible, from the outward character alone of the slag, to judge correctly as to its composition.

In this difficulty, valuable assistance may be derived from frequent determinations of the density of the slag produced. These may be made, in two or three minutes, by Jolly's spring balance (described at page 59 of Brush's Determinative Mineralogy), and an accurate judgment may be formed from them of the proportion of silica that the slag contains; the more siliceous slags, if otherwise similar in composition, being in all cases the lighter.

Thus in smelting siliceous silver ores with galena, eight samples of slag, varying in density from 3·44 to 3·88, contained percentages of silica varying from 37·6 to 30·4.

The following densities and corresponding compositions of different slags illustrate generally their increase of density as the percentage of silica decreases:—

Where produced.	Sp. gr.	SiO_2.	Al_2O_3.	FeO.	CaO.
Iron blast furnace, Wyandotte	2·85	55·0	Undetermined	..	..
Copper Works, Detroit	3·04	43·31	26·22	..	27·40
Germania Works, Utah	3·81	28·01	Undetermined	48·10	12·37
Eureka Consolidated Works, Nevada	4·18	26·47	"	61·62	2·73
Wyandotte Rolling Mills (heating furnace slag.)	4·29	25·49	"	75·06	.

At the Wyandotte Silver Smelting Works, the smelting of the ore goes on regularly and cleanly, and no incrustations are deposited in the furnace, when the specific gravity of the slag is kept between 3·6 and 3·8. The charge smelted contains a pro-

portion of tap or mill cinder from the iron works. The proportion of this that is added is greater or less, according as the slag that the furnace yields is found to be less or more dense.

W. H.

Penetration of Wrought-Iron Armour Plates by Projectiles.

By M. MARTIN DE BRETTES.

(Revue universelle des Mines, vol. v., 1879, p. 463.)

In 1870 the Author showed that the effects of shot fired against wrought-iron armour plates, up to that time not exceeding 9 inches thick, were closely represented by the formula

$$T = 0 \cdot 11\, e + 0 \cdot 0001\, e^2,$$

where T denotes, in tonnes-mètres per square centimètre of the transverse sectional area of the projectile, the power necessary to pierce through a plate of which e is the thickness in centimètres. For English dimensions the equivalent formula is found to be

$$F = 0 \cdot 9\, t + 0 \cdot 0021\, t^2,$$

where F represents foot-tons per square inch of section of the projectile, and t is the thickness of the plate in inches.

Experiments subsequent to 1870—such as those at Spezia in Italy, with a 100-ton gun, firing a 2,000-lb. projectile 17 inches in diameter, against a plate 22 inches thick—have now led to the modification of the above formula as follows, putting r for the radius of the projectile in centimètres and inches respectively:—

$$\left.\begin{array}{l} T = (0 \cdot 11\, e + 0 \cdot 0001\, e^2) \times (1 \cdot 18335 - 0 \cdot 01763\, r) \\ \text{or } F = (0 \cdot 9\, t + 0 \cdot 0021\, t^2) \times (1 \cdot 18335 - 0 \cdot 04478\, r) \end{array}\right\} \quad (A)$$

If it be preferred to estimate the power of penetration T_1 or F_1 per lineal centimètre or inch respectively of the shot's circumference, this is obtained from the foregoing formula by the relation

$$T_1 = \tfrac{1}{2}\, r\, T, \quad \text{or} \quad F_1 = \tfrac{1}{2}\, r\, F \; . \; . \; . \; . \; . \; . \; . \; . \quad (B)$$

The results calculated from these formulæ, for projectiles $5\frac{3}{4}$ to 17 inches in diameter, fired against armour plates of 6 to 22 inches thickness, are shown by the Author to agree closely with those actually obtained in the experiments made.

If W be the weight of the projectile in tons, and v its velocity in feet per second on striking the plate, then

$$F = \frac{W}{\pi r^2} \times \frac{v^2}{2g}, \quad \text{or} \quad F_1 = \frac{W}{2 \pi r} \times \frac{v^2}{2g} \; . \; . \; . \; . \; . \quad (C)$$

Either of these last equations, together with the corresponding previous formula for F or F_1 respectively, enables the remaining two of the five quantities F (or F_1), and r, t, v, W, to be determined, when any three[1] of them are given.

A. B.

Ericsson's Torpedo Gun.

(Army and Navy Journal (New York), October 4, 1879, p. 162.)

Captain Ericsson had been for some time maturing designs for the propelling his high-speed torpedo by compressed air, but without internal machinery. The use of compressed air—by which he had obtained on trial a mean rate of 53 nautical miles (per hour?) for the first 250 feet, at the pressure of 150 lbs.—has now been abandoned, the torpedo being treated as a projectile and discharged from a gun. Although a special boat, the "Destroyer," fitted with air-compressing machinery, had been constructed for the service of the torpedo, the present apparatus indicated a new departure in this class of warfare which, if successful, will render air-compressing superfluous. The present method of manipulation is based on the fact that by suitable treatment, the violent energy of gunpowder may be made available in propelling the heavy, bulky, and comparatively weak body of the torpedo without crushing or splitting it. Captain Ericsson's request for the loan of a 15-inch navy gun and carriage having been acceded to by the United States Government, a cylindrical extension, having the same bore as that of the gun, was secured to the latter by a hinged muzzle-ring bolted to the termination of the chase. This cylindrical extension had for its object the sustaining and directing of the torpedo, which would otherwise greatly overhang. (The illustration shows an unchambered cast-iron gun of the well-known "soda-water bottle" shape, the hinged tube, presumably of the same material, being two-thirds the length of the bore of the gun and half of its thickness at the muzzle, the length of the whole being about 22 feet.) The torpedo is 19 feet long, tapering at both ends, and proportioned to carry an explosive charge of 250 lbs. at the head. At the tail is a cast-iron armature to balance the weight of the charge and to take the thrust produced by firing the gun. The hinge enables the gunner to swing the extension on one side, to facilitate sponging out. The tail end of the torpedo is made blunt, in order to withstand the crushing effect of the great pressure.

A cast-iron piston accurately fitting the bore of the gun is inter-

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[1] The Author says when any *two* are given the remainder can be determined: overlooking the circumstance that of the above equations two only are independent, namely (A) and (C); while (B) presents merely a trifling modification of (A).—A. B.

posed between the charge and the torpedo. The front of the piston is deeply cupped, and holds a cylindrical elastic cushion composed of disks of pasteboard, faced with a metal disk of larger dimensions, which loosely fits the aperture of the piston. Against this metal disk abuts the blunt end of the torpedo. The charge is 8 lbs. of powder, composed of hexagons weighing 96 grains each, and contained in a flannel bag. The latter is pressed against the bottom of the bore by a slender iron rod inserted in the base of the piston, and bearing against a disk or wad in front of the charge. By this means an air space is secured between the charge and the piston, 13·83 times greater than the volume of the charge, and 22·2 times greater than an equivalent amount of solid powder. This air space is an essential feature of the design. In the trials, notwithstanding the fact that the cubic contents of the gun in the rear of the propelling piston at the time of leaving the bore were nearly 112 times greater than the volume of the charge, a bright flame issued from the mouth of the gun at each discharge, following the piston for nearly 8 feet. The internal pressure indicated by the flame after such an expansion of volume can only be accounted for by assuming the combination of the powder gases to be perfect, owing to the presence of a large volume of atmospheric air. This is considered very important, as proving that the explosive energy of gunpowder is not, as generally supposed, a mere momentary development of energy. The result of the trial is stated to be conclusive in this respect, showing that the developed power may be controlled, and to some extent regulated as the expansive force of permanent gases is regulated.

The torpedo employed during the trials was of wood, and exactly fitted the bore of the 15-inch gun. Its weight, including the piston, was 1,281 lbs. During the first experiments, which were made on the west side of the Hudson, two torpedoes completely disappeared by entering the water at a considerable angle and penetrating the soft bottom. The trials were afterwards continued at the Horse Shoe, near Sandy Hook, where the bottom is of firm sand. At each discharge the propelling piston dropped into the sea after parting company with the torpedo, but was mostly recovered. Spare ones were of course provided in case of loss. The inclination of the torpedo during flight can be accurately regulated by attaching to its head, on opposite sides in the horizontal plane, thin disks placed at an angle of 13° to the axis, the regulation being effected by simply altering the width of the disks. No recoil was experienced during the trials, although the friction gear attached to the slides had been but slightly tightened. Captain Ericsson has, accordingly, offered to build for the United States ordnance department, rotary gun-carriages without slides, suitable to be placed on the decks of vessels.

F. G. D.

Counterbalance Gas Regulators. By J. Endlweber.

(Journal für Gasbeleuchtung und Wasserversorgung, vol. xxii., p. 154.)

The Author refers to the previous consideration by A. Thiem of the method of counterbalancing gas-pressure regulators, by which the adjustment of the sinking depth of the regulator is rendered perfectly automatic; and he presents a general statement of the theoretical principles. Thiem's regulator consists of the usual receiving bell, and a pulley over which the rope of a counterbalance weight is passed, this weight being sufficient to equilibrate the receiving bell. To the axis of the pulley is fixed a toe cam, and to the point of this cam is attached a suspension rope, carrying a smaller weight intended to counterbalance variations in pressure. The Author devotes lengthy mathematical consideration to the curve to be given to the toe cam, as well as upon the polar equation for the construction of this curve. As the bell descends into the well, the toe cam is so arranged that the point of suspension of the small counterbalance weight approaches to the axis of the pulley along a helicoidal curve, the curve given to the face of the cam round which the suspension rope rolls itself. The generating point of this curve, formed by the extremity of the radius vector of the curve, is situated at the right angle of a triangle, the hypotenuse of which is equal to the product of the length of the suspension rope, when the bell is raised to a given distance into the radius vector, the base of the triangle preserving a constant value for all angular variations. By this arrangement variations of pressure are accurately followed, since the curve described by the point of suspension of the counterbalance weight accurately represents those variations, and does not remain fixed, as occurs with the circular curve traced out by points on the circumference of the pulley.

E. S.

Bourdon's Steam-Jet Extractor for Gas Retorts.

(Annales Industrielles, July 20, 1879, col. 81.)

Bourdon's steam jet extractor acts on the principle of Giffard's injector. The gas leaving the retorts is drawn by a jet of steam through the discharge pipe. The force of the jet is automatically regulated, according to the rate of production and pressure of the gas in a bell receiver, by an adjustable needle within the steam-nozzle, moved inwards or outwards by a simple movement produced by the rise and fall of the bell of the receiver or regulator. The mixed current of gas and steam is passed through a surface-condenser, where the steam is condensed, and whence it is passed on for collection with the other condensible products. The condensation water holds in ammonia an amount equivalent to nearly

1 lb. of sulphate per cubic foot. That the resistance may be minimised, the condenser should be placed as near as is practicable to the induction-jet. For the most efficient action, the pressure of steam should be at least 4 atmospheres effective; 6 atmospheres is better. The condensing surface consists of small tubes surrounded by water, having an area of about 37 square feet per 1,000 cubic yards of gas. When dry steam of 6 atmospheres is used, the proportion of condensing surface may be reduced by one-third. The advantages of the steam extractor consist in its simplicity and its self-action. The supply of steam is generated by the waste heat of the ovens; but the consumption of steam is greater than in the case of ordinary mechanical extractors.

D. K. C.

On a New Standard of Light. By L. Schwendler, M. Inst. C.E.

(Proceedings of the Asiatic Society of Bengal, April 1879; and Journal ditto, vol. xlviii., p. 83.)

The Author illustrated his Paper by exhibiting an actual standard. The new standard of light consists of a piece of pure sheet platinum of a U shape, cut accurately to fixed dimensions. When a sufficiently strong electric current is made to pass through the platinum, it becomes white hot, and emits a brilliant light. He showed experimentally how the intensity of this light could be varied—*i.e.*, the magnitude of the standard altered—by varying the current, and that when the current was kept constant, the light was rigorously constant also.

Mr. Schwendler defines the new unit of light as the quantity of light emitted from a piece of pure platinum weighing x grammes, and having the most convenient shape and size, when a constant current of y webers per second passes through it.

The advantages of the new standard are: The light is constant if the current is kept constant; it allows a correction to be made for the variation of the current when this variation is known; it can be reproduced accurately anywhere; its magnitude can be altered to any extent to suit certain practical purposes by simply varying the elements of weight, shape, and size of the platinum, or the strength of the current passing through it; it does not alter of itself, either in intensity, size, or position, and therefore most accurate photometric measurements can be made with it; the standard can be easily made to fit into any adopted system of absolute units. Hence the new standard fulfils all the recognised conditions of a perfect and rational standard, and Mr. Schwendler therefore proposes it should be adopted in future in England and India in lieu of the standard candle.

Mr. Schwendler concluded by saying that there would be no practical difficulties in the introduction of the new standard for technical purposes. Gas companies and other corporations that

may in time be formed to supply that necessary commodity "light" to the general public, would find it easy and satisfactory to themselves to use such a reliable standard for measuring the light they sell; and the public, on the other hand, would then know correctly the quantity of light they receive, and for which they had to pay.

Chemical Researches on the Formation of Coal.

By E. Fremy.

(Comptes rendus de l'Académie des Sciences, vol. lxxxviii., p. 1048.)

These experiments were undertaken with the object of discovering, if possible, the substances to which coal owes its origin, and also the conditions under which the metamorphosis of structure took place. In some preliminary investigations into the different compounds which occur in the vegetable world, a new and important substance was detected in considerable quantity in wood. It has been named vasculose by the Author, who attributes to it the difference in the physical properties of various kinds of wood. It is present in oak wood to the extent of 30 per cent., and appears to bind together the fibres of the wood in which it occurs. Numerous experiments were made with the object of finding some chemical test to distinguish wood, peat, lignite, and coal from each other. It was found that while wood is not sensibly attacked by a dilute solution of potash, peat yields a considerable quantity of ulmic acid. Lignite also contains a small quantity of ulmic acid, but may be distinguished from wood, peat, or coal, by treating it with nitric acid, in which it is soluble. True coal and anthracite are insoluble in acids or alkalies. The method employed for the synthesis of coal was to heat different substances of vegetable origin for several hours at a temperature of 392° to 572° Fahr. in closed iron tubes. Cellulose, or the substance which forms the skeleton of plants, when treated in this way, was converted into a black substance, which retained its organic structure and offered no resemblance to coal. Other substances produced in large quantities by the vegetable world were next submitted to a similar test. Sugar, starch, gum, and chlorophyll were converted into a substance resembling coal. It was black, brilliant, and insoluble, and when heated to a red heat, gave off water, gas, and tar, the residual product being a hard coke. The following analyses of these artificial coals, compared with that of a natural coal, confirm the resemblance:—

	Carbon.	Hydrogen.	Oxygen.	Ash.
Coal made from sugar . .	66·84	4·78	28·43	..
" " " starch . .	68·48	4·68	26·84	..
" " " gum arabic	78·78	5·00	16·22	..
Natural coal from Blanzy .	76·48	5·23	16·01	2·28

These substances therefore can be directly converted into

coal, and it only remained to prove how the woody tissues also could be so transformed that their conversion might be effected under the same conditions. In peat it was found that the cellulose or ligneous fibre had become changed into a substance termed ulmic acid. This acid, by the means already indicated, was easily converted into artificial coal. The longer the action of the heat was maintained, the greater was the proportion of carbon in the coal produced. It appears therefore that the plants to which coal owes its origin were first changed into peat, and, after their organic structure had been destroyed by a kind of peaty fermentation, the final change into coal took place.

W. F. R.

The Holly System of Steam Heating.

(Scientific American, August 23, 1879, p. 114.)

In this system, steam generated at a central station is supplied to the surrounding neighbourhood for the purposes of heating, cooking, and motive power[1], through underground pipes, protected against radiation, and provided with expansion joints, meters, and pressure regulators. The feasibility of the project was first tested in January 1877, with 3 miles of underground pipes, at Lockport, in the State of New York; the trial proved a complete success. Junction boxes, allowing for the free longitudinal expansion and contraction of the mains, are fixed at intervals of 100 to 200 feet; and from these are carried service pipes underground into the cellars of buildings to be supplied. The pipes slope downwards from the mains; and the water of condensation draining down them, having a temperature due to the steam pressure of say 50 lbs. per square inch, accumulates at a regulating valve, through which, when intended for heating and cooking, it is wire-drawn to such an extent that by the reduction of pressure it is largely reconverted into steam of little more than atmospheric

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[1] It may be of interest here to record, that a similar project for the supply of steam power was submitted in 1858 to Sir William Fairbairn, who expressed in a letter to a friend his views regarding it as follows :—"I should have considerable misgivings about [the] project of a General Steam Supply company for towns. In my practice I have always found the transmission of power by steam more expensive than by shafting or other means adopted for that purpose. When the friction of the pipes, loss of heat by radiation, &c., are considered, I think it will be more expensive in conveying steam to an engine at a distance than taking the engine to the steam. In some cases, it is true, if the mountain won't go to Mahomet, Mahomet must go to the mountain; but I have always found it eligible to bring the steam generator as close to the moving power, or the spot where the steam is used, as possible. Impressed with these views, I fear I cannot look upon this project as one likely to succeed; and before any attempt of that kind is made I would strongly advise a series of experiments to be instituted, in order to show the ratio of the loss of heat as the distance of transmission is increased, and by careful comparison with existing methods to determine how far it would be expedient to enter upon the undertaking."—A. B.

pressure. In Mr. Holly's "atmospheric radiator" the internal steam pressure and external atmospheric pressure are equal, admitting of the use of very thin sheet metal in its construction. The distributing pipes are freed from water by a steam trap. The water of condensation is all collected in a closed tank, from which it is forced by steam pressure at intervals into a cistern at the top of the building. Sketches are given of the principal contrivances devised by Mr. Holly for carrying out his plan. Steam fire-engines supplied by this means would need no boilers of their own; and snow and ice can be cheaply removed from the streets.

A. B.

Experimental Determination of the Velocity of Light.

By A. A. MICHELSON, Master U.S. Navy.

(American Journal of Science and Arts, vol. xlviii., p. 390.)

These experiments were made with a revolving mirror apparatus, but differing in some details from that employed by Foucault, whose results, the Author thinks, cannot be relied upon within less than 1 per cent. In the Author's apparatus the distance between the mirrors was 2,000 feet. The radius was about 30 feet, and the speed of the rotating mirror was about two hundred and fifty-seven revolutions per second. The deflection exceeded 133 millimètres (5·236 inches), or two hundred times as great as that obtained by Foucault, with, it is claimed, a proportionate decrease of error. The revolving mirror was actuated by a turbine on the same shaft. The motive power was a current of air furnished by a blower, the pressure being kept constant by means of a water gauge. To regulate and measure the speed of rotation, a tuning fork, bearing on one prong a steel mirror, was vibrated by a current of electricity. This fork, which had been compared with a standard Ut_3 fork at the Stevens Institute, made one hundred and twenty-eight vibrations per second. It was so placed that the light from the revolving mirror was reflected to a piece of plane glass in front of the eye-piece, and thence to the eye. The apparatus for measuring the deflection of the images, resulting from the revolution of the mirror and vibration of the tuning fork, consisted of an accurate screw with divided circle. To the frame was attached an adjustable slit. On the screw travelled a carriage supporting the eye-piece, which was an achromatic lens having in its focus a vertical silk fibre. The slit, being nearly in the same focal plane as the silk fibre, was bisected by the latter, and a reading of the scale and of the circle taken. The screw was then turned until the silk fibre bisected the reflected image of the slit and another reading taken. The difference between the two gave the deflection.

Elaborate precautions were observed to eliminate possible errors: from the rotation of the mirror being in one direction; from a regular variation in speed during every revolution, should such

exist; from the vortex of air about the mirror affecting the deflection; and finally, personal error.

A table of one hundred observations is appended, each being the mean of ten separate observations. The general result is as follows:

Mean of all the observations .	299,728	
Correction for temperature . .	+ 12	(of steel tape, scale, and screw.)
Velocity of light in air . . .	299,740	
Correction for vacuum . . .	+ 80	
Velocity of light in vacuo . .	299,820	kilomètres (186,278 miles), per second.

The Author claims that this measurement is correct within one ten-thousandth part.

F. G. D.

Electric Fuses. By G. Cabonellas.

(Mémoires de la Société Nationale des Sciences Naturelles et Mathématiques de Cherbourg, vol. xxi., p. 273.)

To arrive at a simplified value of the relative sensitiveness of similar fuses, the Author considers two fuses of the same electrical resistance, constructed with a cylindrical wire of metallic alloy. With fuses having the same electrical resistance, the quantity of heat developed in equal time by the same current may be considered as constant. To put the fuse in operation, it is necessary and sufficient that an element of the fuse composition should absorb the quantity of heat necessary to inflame it. The total intensity of the heat action generated by the current in the wire will be inversely proportional to the cylindrical surface of the wire; and the sensitiveness of two fuses A and A′, will be as $\frac{d' \, l'}{d \, l}$, d being the diameter, and l the length of the wire. The equation for the electrical resistance of cylinders $\frac{l}{d^2} = \frac{l'}{d'^2}$, where $\frac{l}{l'} = \frac{d}{d'^2}$, also relates to the sensitiveness of the fuses A and A′, which will then be as $\frac{d'^3}{d^3}$; or, with a wire surrounded by inflammable composition, the relative sensitiveness of the fuses will be inversely as the cubes of their diameter, or $l^{\frac{3}{2}}$. Fuses of the same electric resistance should have the smallest possible length of wire, and that of a very fine diameter.

With a given length for the wire, the fuse is rendered more sensitive by twisting it into close spirals, for then the calorific action of the several elements of the surface of the wire, unite in heating the same element of the fuse composition. The best theoretical arrangement consists, not in spirals arranged helically, but in close spirals, in one or more coils, forming a small imaginary sphere,

the interior of which contains a quantity of the composition. The diameter of the fuse wire and its electrical resistance play a most important part. When helicoidal spirals are arranged cylindrically one upon the other in a single line, they fulfil many of the theoretical conditions, and have the advantage of being easily made in course of manufacture by twisting round the cylinder serving as a mould. But the spirals must not touch each other, or make accidental contact.

The quantity of heat developed in a unit of time should be in proportion to the increase in length of the wire employed, and this length it is only possible to increase in a given fuse by the addition of spirals.

If a series of fuses of the same electric resistance be considered, in which the diameter of the fuse wire gradually diminishes, and the length of these wires decreases at the same time, the importance of the spiral form will become less. A point will be arrived at, where no advantage is to be gained from the use of a spiral, when the diameter will become sufficiently small for the electric resistance to be included in an extremely short wire. When this length is reduced to the lowest practicable limit, the sensitiveness of fuses of different electrical resistance also varies nearly inversely as the cubes of the diameters of the wires. In practical work numerous advantages follow from a reasonable suppression of the spiral form. The platinum wire may be made very short by employing a Wollaston wire of a metal alloying with platinum, bent to an acute angle, the apex of which is immersed in a chemical reagent to form the juncture.

The Author proceeds to establish mathematically the absolute and relative values of heat, sensitiveness, resistance, and diameters of the fuse wires, and arrangement of the electro-motor. He points out that the sensitiveness of two fuses will be related as the quantities of heat multiplied by the inverse ratio of the products of the lengths by the diameters, and that the sensitiveness of a single fuse will increase more quickly than the quantity of heat developed, with increasing values of the resistances, which, in practice, are causes of the increase of the heat; deducing the law that the resistance of the fuse should, for maximum sensitiveness, be equal to all other resistances in circuit. According to the Author, the resistance of the earth-plate should be taken into account. Want of uniformity in the manufacture of fuses has led to the practice of furnishing submarine mines with several fuses in derived circuit. To obtain a maximum under these conditions, it is necessary to know what arrangement of n given couples, and what resistance of fuses, will correspond to a maximum production of heat in each of M fuses contained in M derivations to earth. Calling i the current strength in one fuse, and I the current strength in the whole:

$$i = \frac{I}{M},$$

As
$$I = \frac{a\,E}{\frac{a^2}{n}R + r + \frac{e}{M}},$$
$$i = \frac{a\,E}{M\left(\frac{a^2}{n}R + r + \frac{e}{M}\right)}.$$

To render this expression a maximum
$$K\,e\left(\frac{a\,E}{M\left(\frac{a^2}{n}R + r + \frac{e}{M}\right)}\right)^2;$$

there will be a maximum of $a\,n$, where a is the unknown number of cells in tension,

or
$$\frac{K\,E^2}{4} \times \frac{1}{M} \times \frac{1}{\frac{R}{n} + \frac{r}{n^2} + \frac{1{,}600}{n^2}};$$

Whence $e = M\,(m\,R + r + 1{,}600)$, the number 1,600 being estimated as the number of mètres of telegraph wire equivalent to the exterior resistance attributable to the earth connection. The resistance of the fuse giving a maximum of heat for a given seriation is $e = M\left(\frac{a^2}{n}\,R + r + 1{,}600\right)$.

The Author tabulates formulæ for maximum condition of arrangements of fuses, batteries, and derivations likely to occur in any application of electricity to the firing of explosives.[1]

E. S.

NOTE.—The Author does not in the foregoing take into account failures arising from the solder, holding the fuse wire, melting before the platinum wire reaches the temperature of ignition; from want of contact between the wire and fuse composition, and from other similar causes.—E.S.

Experiments on the Chemical Stability of Explosives.

By Captain F. HESS.

(Mittheilungen über Gegenstände des Artillerie- und Genie-Wesens, 1879, No. 6, p. 345.)

These experiments were undertaken to test the liability of various explosives to spontaneous decomposition. The ordinary method of exposing a small quantity of the substance under examination to

[1] This table is practically the same as that previously given in these Abstracts for the production of maximum light, in which all the series of electric lights are arranged upon one or more circuits; the conditions are similar in both cases, although the heating effect is of less degree.—*Vide* Minutes of Proceedings Inst. C.E., vol. lviii., p. 415.

a temperature of 158° Fahr. in a closed vessel for several days suffices in some instances; in others a more accurate test is necessary. Professor Abel's method is useful when the substance tested does not originally contain volatile bodies which liberate the iodine of iodide of potassium; but, in reality, it only indicates the time required to produce signs of decomposition. It does not show the rate at which this decomposition increases, nor whether it finally results in explosion. None of the commercial nitro-compounds are chemically pure, and it has been found that the impurities are the first to decompose. Once these have disappeared, some explosives undergo no further change. It is therefore necessary to follow up the decomposition through its progressive stages, and for this purpose the Author's apparatus was constructed. About 7·7 grains of the substance was weighed into a porcelain vessel, which was then placed in a glass tube passing through a hot-air bath. Through this tube was passed a current of air, 32 gallons in six hours, previously purified and dried. All gaseous products of decomposition passed with the air into a solution containing starch and iodide of zinc. In the presence of nitrous vapours this solution becomes blue, the intensity of the colour showing the degree of decomposition of the substance tested. The first traces of chemical disintegration were indicated by a blue or violet tinge in the liquid adjoining the orifice of the tube through which the gases entered. This was followed by a blue ring in the same spot, after which the whole liquid became coloured. The following table (see next page), embodies the chief results of experiments made at a temperature of 158° Fahr.

Another table is given of the effects of a temperature of 212° Fahr. The maximum of decomposition was reached much sooner at the higher temperature; in most cases within an hour. The presence of soluble salts of iron seems to diminish the stability of dynamite. Long-continued immersion in water renders gun-cotton much less liable to decomposition; but it appears that pure nitroglycerine is more reliable than ordinary washed and purified gun-cotton. Those dynamites possess most stability the absorbent substance of which chiefly consists of carbonates of the alkaline earths, these latter neutralising any acid originally present or subsequently formed. Infusorial dynamite usually contains soluble silica; its stability is seldom as great as that of nitro-glycerine. Taking into account the experience gained with dynamite in the Austrian army during the last ten years, a nitro-compound may be considered fit for storing when a temperature of 158° Fahr. does not produce the first stage of decomposition in less than ten minutes, the second in fifteen minutes, the third in twenty minutes, and the distinct coloration of the test liquid in thirty minutes. Nitro-mannit must be pronounced unfit for storing, even for a short time.

When the explosives to be tested contain *per se* volatile substances which might act on the test solution, or when the gases evolved during decomposition contain no nitrous vapour, the

Name of Explosive.	Minutes before the appearance of: A slight trace of Colour.	A Blue Ring.	Slight Colour throughout Liquid.	Distinct Colour.	Remarks.
Nitro-glycerine	226	637	1,049	1,777	Extracted from infusorial dynamite and well washed.
Infusorial dynamite No. 1 .	10	19	41	172	Made with well calcined infusorial earth.
Infusorial dynamite No. 3 .	15	23	29	50	The infusorial earth contained soluble silica and oxide of iron. Acid re-action.
Infusorial dynamite No. 4 .	36	68	532	736	Made in 1871. Infusorial earth well calcined. Reaction neutral.
Gun-cotton dynamite . .	9	17	350	512	Composed of 25 per cent. gun-cotton and 75 per cent. nitro-glycerine.
Compressed English gun-cotton . .	10	347	1,257	1,405	Kept eight years dry, one year under water.
Compressed German gun-cotton No. 1 .	17	23	30	44	Made in April 1879. Contained 30 per cent. moisture. Air-dried.
Compressed German gun-cotton No. 4 .	9	12	65	73	Made in May 1879. Contained 1·5 per cent. soda.
Nitro-cellulose .	8	12	61	77	Used for making "Rhexit."
Nitroxylin . .	12	18	152	173	Nitro-cellulose impregnated with nitrates.
Loose gun-cotton . . .	128	392	not continued		Kept many years in running water.
Blasting gelatine with 1 per cent. camphor	390	560	1,000	1,270	Made in 1878.
Blasting gelatine with 4 per cent. camphor	120	500	1,200	1,350	Do. do.
White dynamite	21	59	1,778	2,018	The absorbent substance was chiefly carbonate of lime.
Cellulose dynamite . . .	36	39	493	513	
Fulgurit . .	18	38	1,682	2,072	Carbonate of magnesia impregnated with nitro-glycerine.
Gun-cotton dynamite No. 2	3	6	8	15	Not quite free from acid.
Nitromannit.	4	6	8	10	Quite free from acid.

above method is not available. In such cases the best index is the volume of gas given off. Professor Abel heated the substance in a vacuum in order to measure the gas; but the Author, wishing to deviate as little as possible from the conditions prevailing in practice, devised an apparatus for heating the explosive in a closed space full of air, and measuring the volume of gas produced. This apparatus consists of a U-shaped tube, one side of which is open,

the other connected with an air-tight receptacle for heating the sample. A small quantity of the explosive having been introduced, mercury is poured into the tube till it attains a certain height. The temperature is then raised, and the gas evolved in the closed end forces the mercury upwards in the opposite limb. The height of the column of mercury thus raised is noted, and from it the volume of gas is calculated. Even this method, however, does not always afford an insight into the stability of the explosive. Nitro-glycerine is partially volatile, its vapour increasing the tension of the gases, and English gun cotton sometimes contains carbonate of ammonia, which has the same effect.

W. F. R.

NOTE.—It having been suggested by the abstractor that the method adopted in the foregoing experiments contained two sources of error: 1stly, the removal of the nitrous acid as soon as generated, which does not occur in practice; 2ndly, the ignoring of the cumulative effect of decomposition in large masses which chiefly depends upon their power of conducting heat, these objections were communicated to the Author. In reply Captain Hess acknowledges the first source of error, but maintains that it may be diminished by careful manipulation. With regard to the second point he thinks that the difference in the conductivity of the various substances tested is too slight to be of importance.—SEC. INST. C.E.

Studies on the Toughening of Glass. By DR. SCHOTT.

(Verhandlungen des Vereins zur Beförderung des Gewerbfleisses, 1879, p. 273.)

The process invented by De la Bastie, and now generally adopted, consists chiefly in plunging the article to be toughened, when at a bright red heat, into a bath of linseed oil and tallow. In the case of drinking-glasses and other hollow vessels, which are plunged head downwards into the bath, after the manner of a diving-bell, due provision is made for carrying off the imprisoned air, by means of an inverted siphon, in order that the oil may simultaneously reach both sides of the glass. When cooled and removed from the bath, the adhering oil is allowed to drop off as far as possible, and the articles are cleansed by washing with soda or a ley of caustic soda. During this process of toughening, from 10 to 25 per cent. of the objects treated crack spontaneously. The broken fragments are of little use, on account of their dirty condition. Sometimes, however, the cracking takes place weeks and months after the articles have been finished. These circumstances, together with the cost of the manipulation, oil, &c., render the toughened ware somewhat more expensive than glass of the ordinary description. No perfectly satisfactory reason has yet been advanced to account for this spontaneous cracking; but it has been noticed that whenever the surface of the glass has been injured by the presence of a foreign substance, as such a particle of coke, or ash, the cracks invariably radiate from such a spot.

The Author carried out a series of experiments on bars of glass, of different compositions, raised to different temperatures, and cooled in various ways. The object of the first series of experiments was to ascertain what temperature of the glass and oil, and what composition of glass, gave the best results. The results may be summarised as follows:—1st, the hotter the glass is when thrown into the bath, the better it is suited for toughening; 2nd, the warmer the bath, the better the results; 3rd, soft half-crystal glass, composed of soda, lead, and lime, gives but little better results than pure soda-lime glass; 4th, the cooler the glass when plunged, the hotter must be the temperature of the bath; 5th, more hollow spaces are formed in the interior of the glass if its temperature be high, and that of the bath low, than if the temperature of the bath be high also; 6th, Bohemian glass is not well suited for toughening.

The next and most interesting series of experiments was carried out on bars of glass treated in different manners, with the object of testing their strength. The bars were cylindrical in form, and rested on two knife edges at a given distance apart; the load was applied at the centre of the bar; from the weight of the breaking-load, and the dimensions of the bar, the strength of the glass was deduced. The following Table (see next page), gives the result obtained.

From the above experiments it will be seen that annealed glass possesses a tensional strength of 5·5 kilogrammes per square millimètre = 3·48 tons per square inch, which is from twice to three and a half times greater than the figure usually given. From the experiments, it would appear that by simply cooling glass in the air its strength may be doubled. As a further result, it may also be stated that the hotter the glass, and the colder the bath, the stronger will be the finished ware. The former experiments, however, proved that when the temperature of the glass is lower (and this is necessary in practice in order that the shape of the article may be preserved during toughening) the temperature of the bath must be taken higher; and thus the conditions of manufacture do not, as a rule, permit of the glass being endowed with maximum strength. As a result of this, glass of such a composition should be chosen as will give favourable results with a low temperature of the glass and a moderate temperature of the bath. For this purpose, a glass rich in silicic acid and poor in lime appears to be best suited.

The average tensional strength of the bars hardened in oil was 27 kilogrammes per square millimètre = 17·1 tons per square inch, or about double the strength of cast iron, and five times the strength of annealed glass; in some instances a strength of 34·2 tons per square inch (equal to that of iron wire) was attained.

The process of toughening in oil, as adopted by De la Bastie, is not suited to the production of plate glass, for it invariably warps the plates, injures their quality, and the consumption of oil and cost of cleaning are very considerable. To obviate these disadvan-

Manner of Cooling.	Diameter in millimètres = ·039 inch.	Length in millimètres.	Breaking Load in kilogrammes = 2·2 lbs.	Breaking Tensional Stress, in kilos. per sq. mm. = ·635 t.n per sq. inch	Breaking Load reduced to normal bar, 10 millimètres diameter, 10 millimètres long.	Remarks.
in annealing oven (1)	10·1	250	9·5	5·87	23·05	Flat surface of fracture.
ditto (2	11·2	250	12·5	5·68	22·31	Ditto ditto.
ditto (3)	11·6	250	11·5	4·69	18·42	Ditto ditto.
carelessly in the air (1)	10·5	250	23·0	12·66	49·72	Wedge broken out 80 millimètres long.
ditto (2)	13·4	300	30·0	9·52	37·39	Wedge broken out 150 millimètres long.
ditto (3,	10·2	250	16 5	9·9	38·88	Wedge broken out 80 millimètres long.
ditto (4)	11·4	300	14·0	7·22	28·35	Wedge broken out 20 millimètres long.
Bath 212° F.						
dull red heat . . (1)	9·5	230	49·5	36·81	144·58	Numerous longitudinal cracks.
ditto . . (2)	10·6	230	66·0	32·47	127·54	
medium red heat (1)	11·7	300	37·7	17·98	70·62	While the load was being increased small splinters were constantly breaking off.
ditto (2)	10·8	350	29·0	20·51	80·56	
bright red heat . (1)	11·0	300	94·5	54·22	212·97	Numerous hollow spaces in the glass. Lively detonation.
Bath 248° F.						
dull red heat . . (1)	10·5	300	32·7	21·58	84·76	
ditto . . (2)	11·1	250	34·9	16·24	63·79	
ditto . . (3)	11·4	250	47·5	23·65	92·89	The breaking off of splinters unusually frequent.
ditto . . (4)	10·8	250	20·7	12·03	47·25	Large open longitudinal crack. Splinters frequently breaking off.
medium red heat (1)	8·9	300	29·5	31·97	125·5	
ditto (2)	9·0	300	31 3	32·83	128·9	
bright red heat . (1)	9·9	250	49·5	32·49	127·6	Bars without flaws, but with hollow spaces.
ditto . (2)	13·4	250	112·5	29·68	116·5	
ditto . (3)	10·7	250	69 55	36·03	141·5	
Bath 248° F.						
dull red heat . . (1)	14·2	250	90·5	20·13	79·07	Splinters flew off while load was being increased.
ditto . . (2)	10·8	300	19 5	11·82	46·42	
medium red heat (1)	9·4	300	45·2	41 6	163 39	Perfect bars.
bright red heat . (1)	11·9	200	120·2	36·3	142 7	
Bath 356° F.						
dull red heat . . (1)	10 3	225	45·5	23 85	93·6	Similar circumstances to other bars brought to dull red heat.
ditto . . (2)	10·3	350	22·0	17·92	70·38	
medium red heat (1)	7·1	200	11·7	16·66	65·43	
bright red heat . (1)	10·8	400	42·5	34·36	134·9	
ditto . (2)	9·1	350	32·7	38·72	152 2	

tages, Mr. F. Siemens, of Dresden, introduced the method of toughening plate glass by laying the red-hot plate between two cast-iron blocks, with carefully got up surfaces. The upper block is counterbalanced, so as not to press too heavily on the glass plate. A contact of a few minutes suffices to effect the object in view. The proper temperature of the cast-iron blocks depends to some extent on the temperature and composition of the glass. As in the case of oil, the strength of the finished glass increases with the difference of temperature between the glass and the cast iron.

G. C. V. H.

NOTE.—"Engineering," August 22, 1879, contains an account of the application of glass to the manufacture of railway sleepers. Tramway sleepers 6 inches deep by 4 inches wide were tested by Mr. Kirkaldy, and were found to break under an average load of 5 tons, the supports being 30 inches apart.—G. C. V. H.

A New Safety Cage for Lifts in Factories, Hotels, etc.

Dr. M. BUSSE.

(Zeitschrift des Vereines deutscher Ingenieure, vol. xxiii., p. 421.)

The Author commences by referring to the numerous and fatal accidents that have frequently occurred with passenger lifts in factories and hotels, instancing particularly one which took place in Paris, and then proceeds to enumerate the conditions which a good mine-cage should fulfil, according to the views expressed by Serlo in his "Introduction to Mining." The chief of these are, that the apparatus must be capable of carrying a load of at least 3 tons with a velocity of 25 to 30 feet per second; that the whole of the gear used must be exceedingly simple, trustworthy, not liable to get out of order, and not requiring any other attention than occasional oiling; that the cage be stopped without jerk; that rubber-springs of any kind are to be avoided, as they are liable to such changes through time as to become untrustworthy; and, lastly, that the cage should be provided with a slanting roof, to prevent the occupants being injured by the rope falling on them should it break. The Author assumes that all these conditions, save the first, must be fulfilled, and states that a maximum velocity of 6·5 feet per second is sufficient for the lifts under discussion. He next enumerates the means generally used for stopping a falling cage, and divides them all into three classes, viz., levers with teeth entering the guides; eccentrics, and wedge motions, giving the preference decidedly to the latter. Four drawings are given of the safety cage, the stopping motion consisting of wedges thrown into gear by an auxiliary rope coiled on a drum carried by the shaft of the pit head pulley, the radius of this drum, plus half the thickness of the auxiliary rope, being exactly equal to the radius of the pit head pulley. The success of

the whole apparatus depends on the nicety with which this last condition is fulfilled; and the Author acknowledges that some little trouble may possibly arise in practice through the difficulty of always keeping the two ropes exactly of the same length, particularly when it is borne in mind that the lifting rope is continually stretching on account of the loads it has to raise. Owing, however, to the moderate height of the lifts it is proposed to work, say in hotels or factories, a maximum of 164 feet, it is hoped this difference in the lengths of the ropes, which it is stated may amount to as much as 4 inches, may not in practice tend to render the system inadmissible. A modified arrangement of auxiliary hand-brake is also illustrated and described.

D. Ha.

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1879–80.—Part I.

END OF VOL. LIX.

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PORT O

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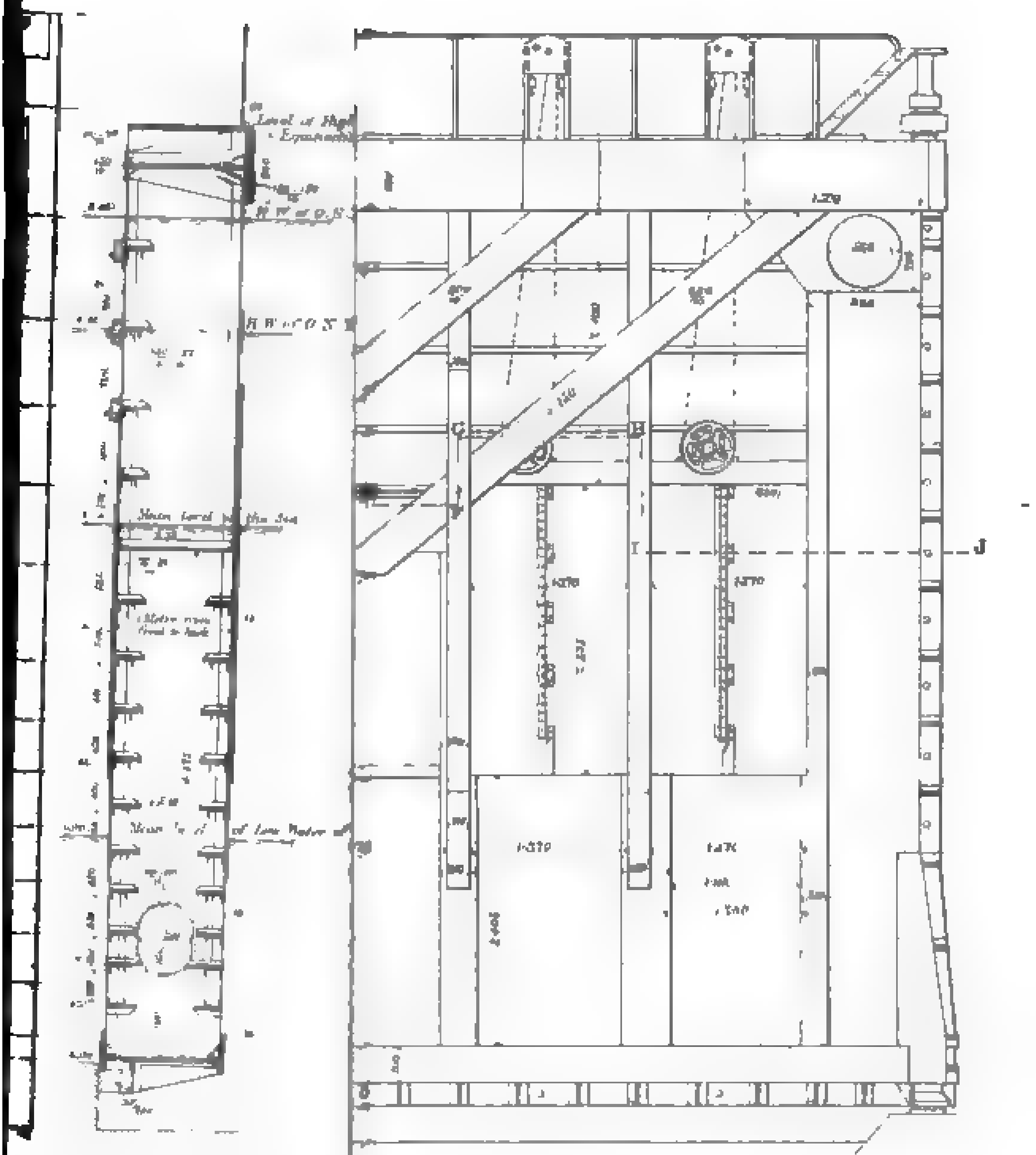
PLATE . 1

Fig 2



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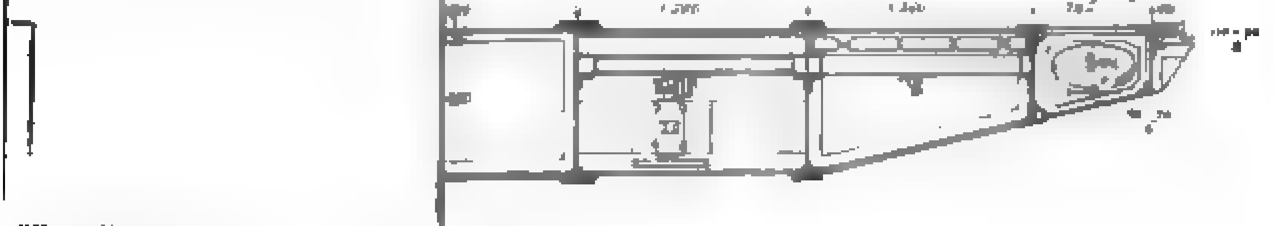

TH.J. PELL LITH. 44 KING ST. COVENT GARDEN

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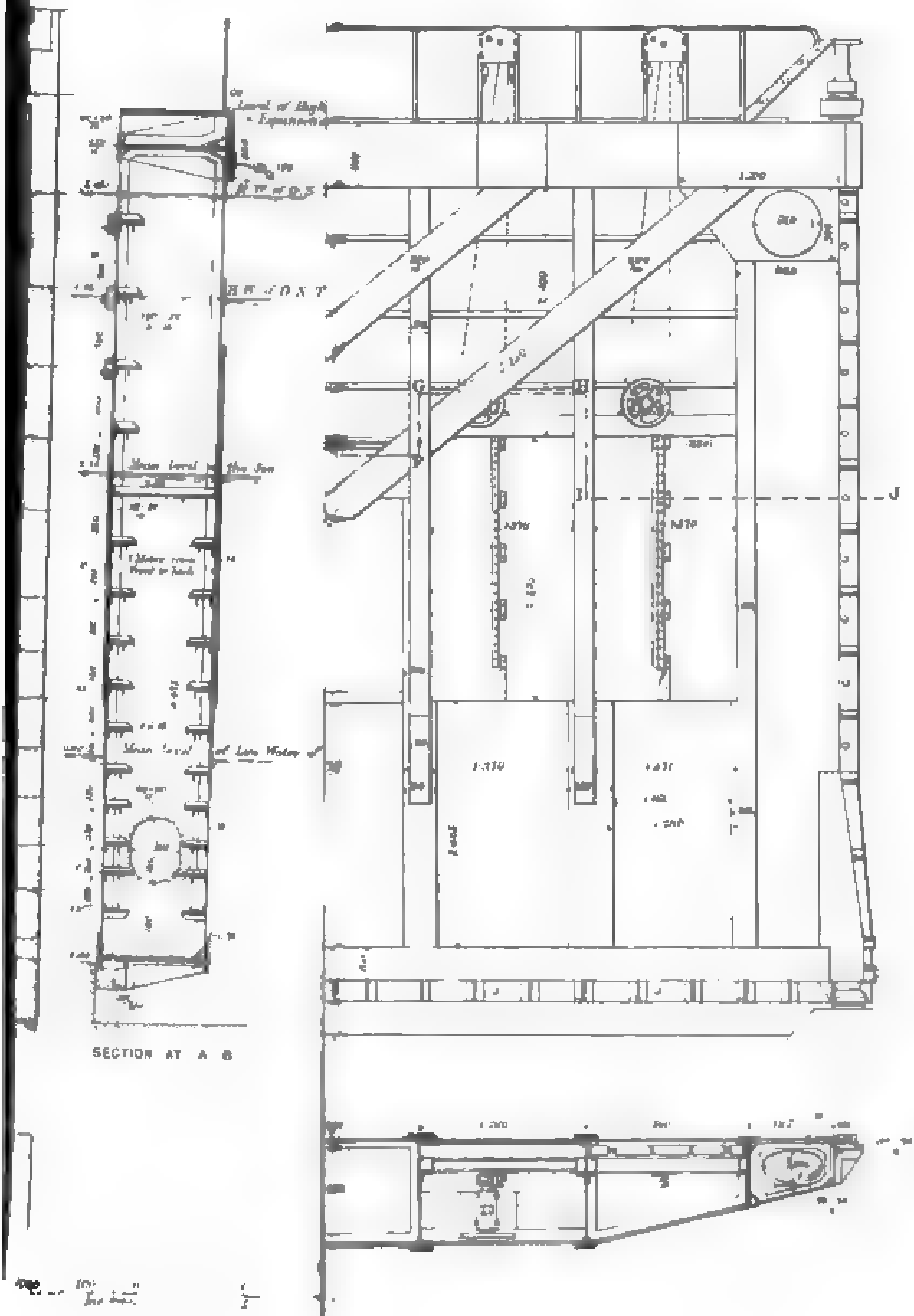
PORT C

LOCKS OF TH

PLATE I

Fig 2



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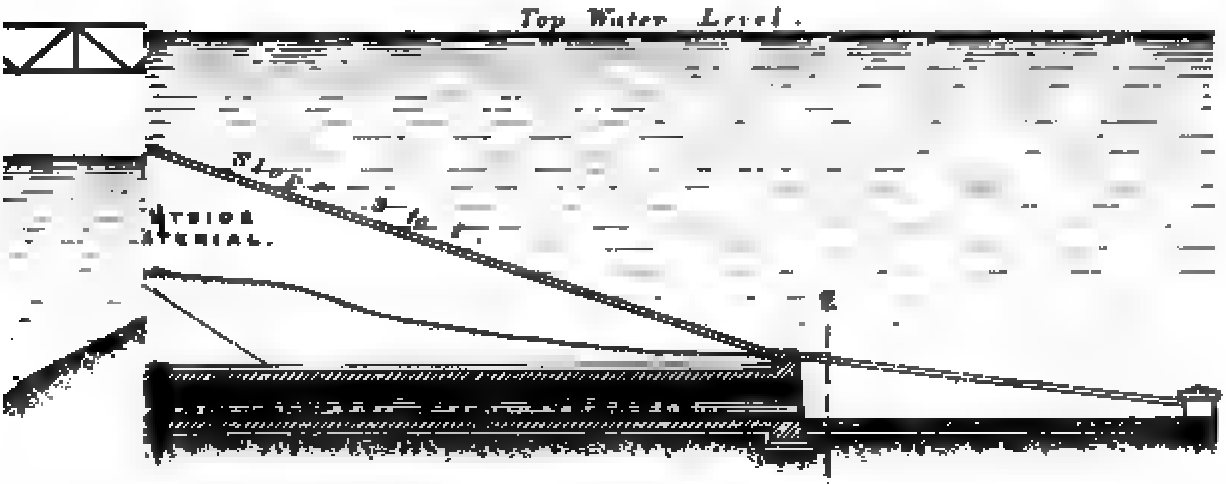
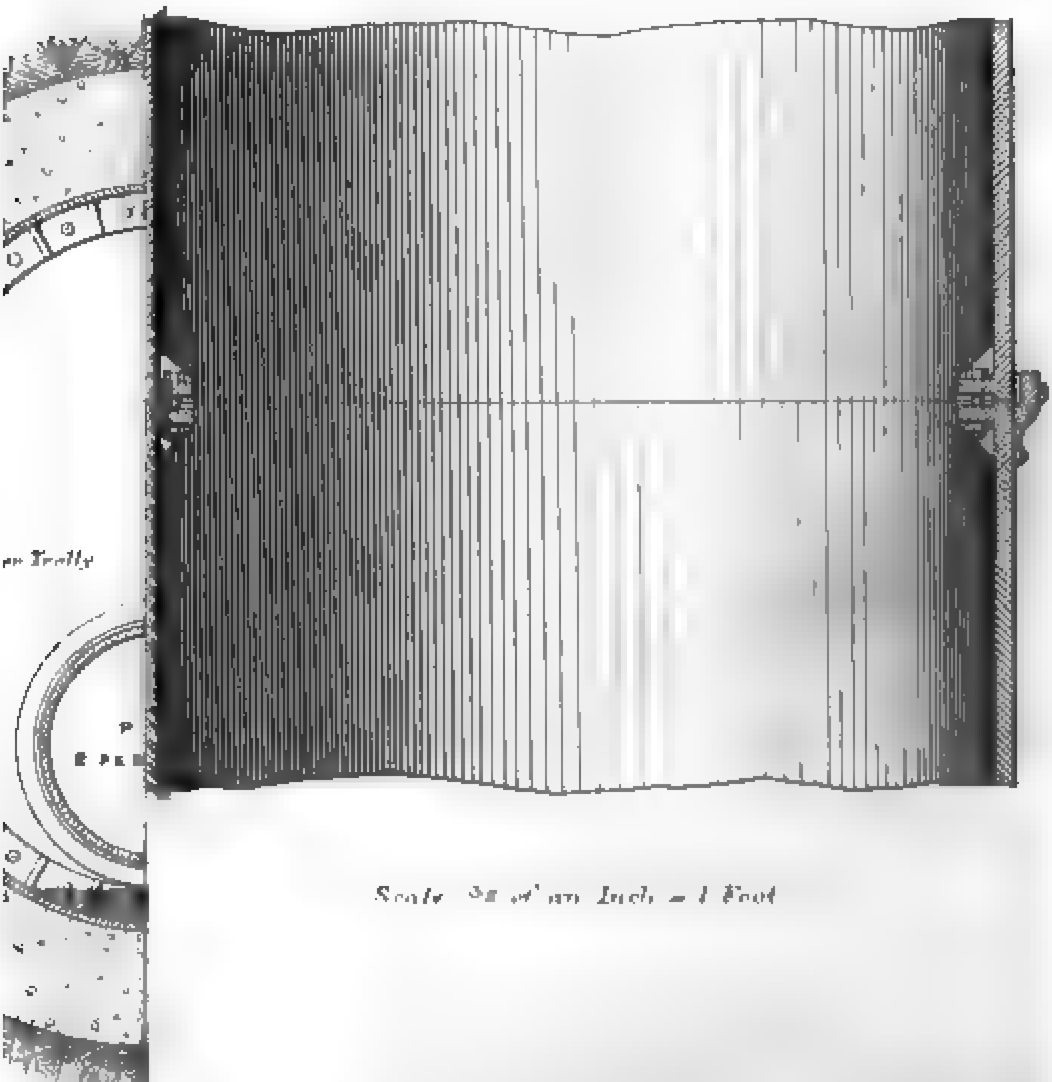


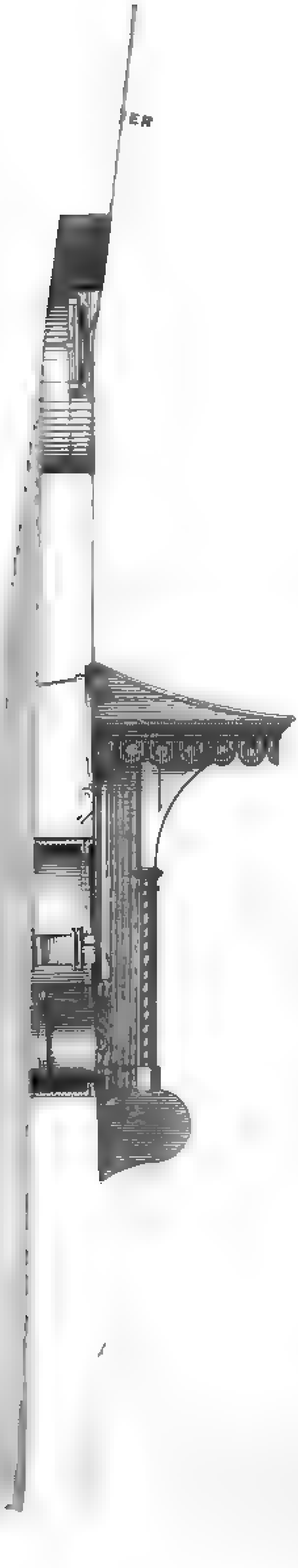
Scale 45 Feet = 1 Inch.

Fig 8.

CTION OF JOINT ULTIMATELY ADOPTED IN THE RINGS OF VALVE TOWER.



Scale ¾ of an Inch = 1 Foot



THOS KELL, LITH 40 KING ST COVENT GARD

PLATE 4.

LEEMING

Fig. 19.

SERVOIR. SECTION OF CULVERT ON LINE A.A, FIG: 8.

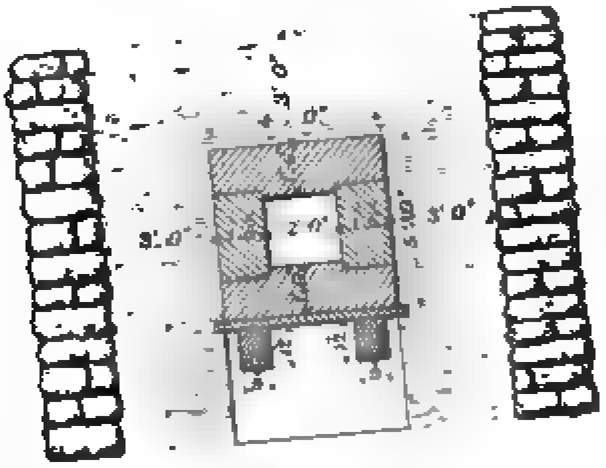
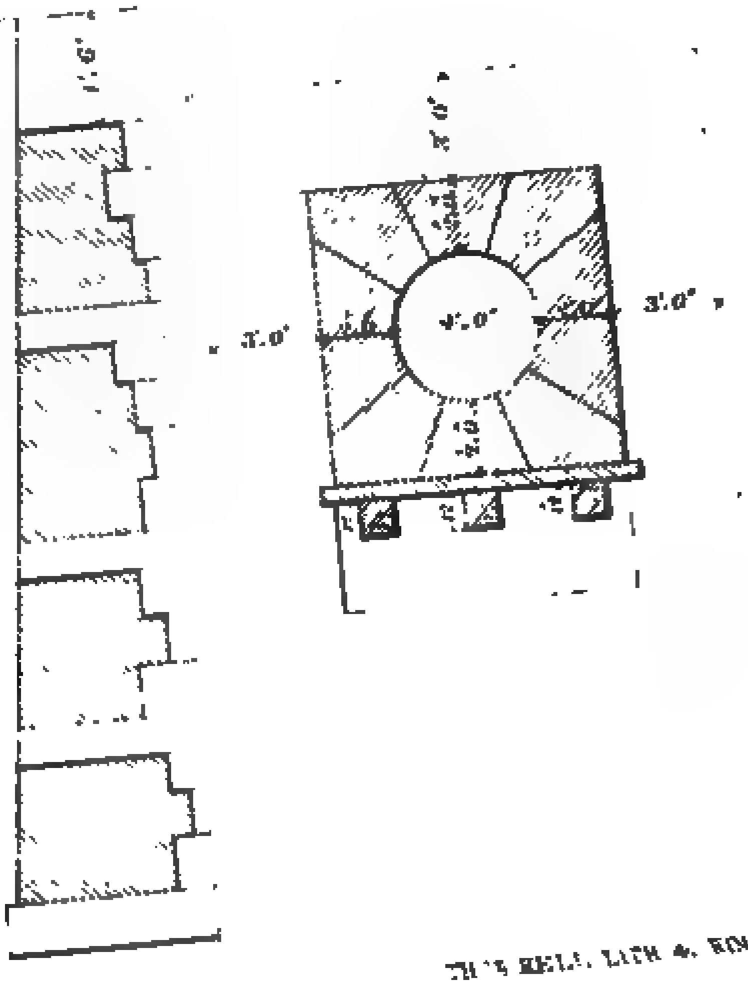


Fig. 20.

SERVOIR. SECTION OF CULVERT ON LINE B.B, FIG: 8.



THOS KELL, LITH 40, KING ST COVENT GARDEN

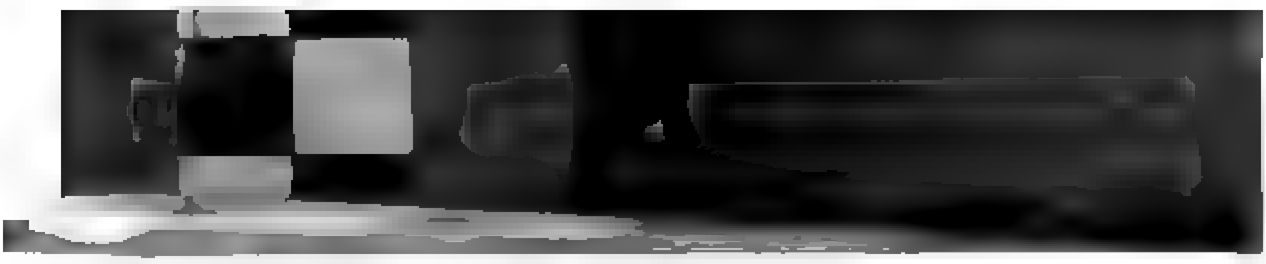


PLATE 5

Fig: 24.

FRONT LONGITUDINAL SECTION.

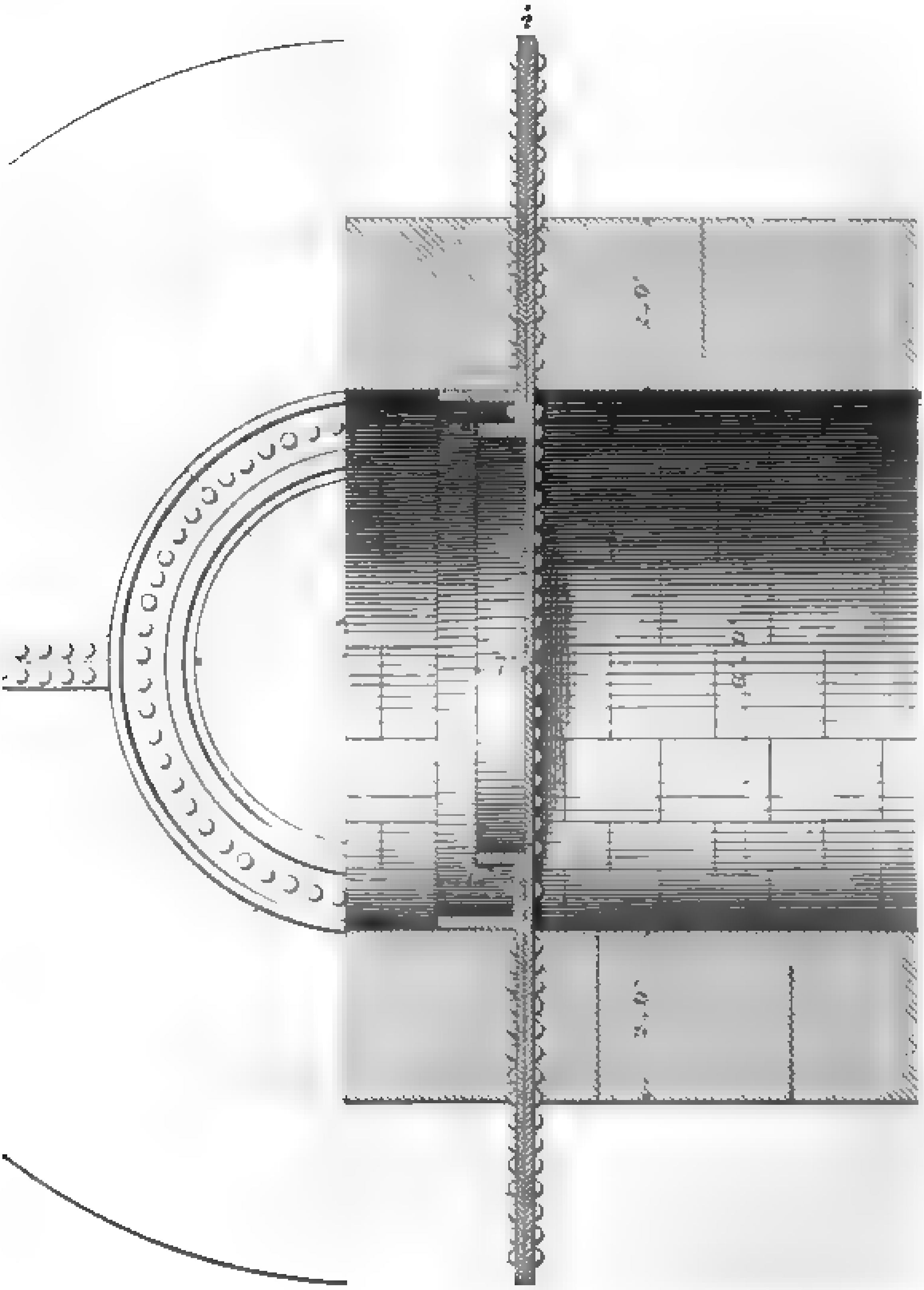
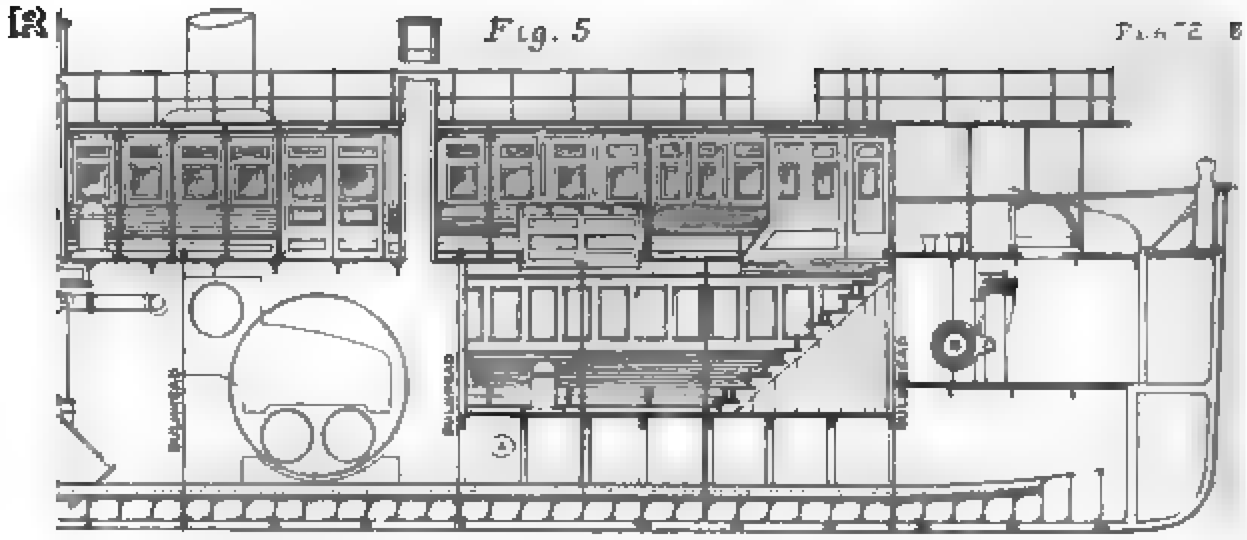


Fig. 5

PLATE 8



B. Athwart Ships Watertight Bulkhead
Bb. Fore and Aft Watertight Bulkhead
A. Manway doors in Bb

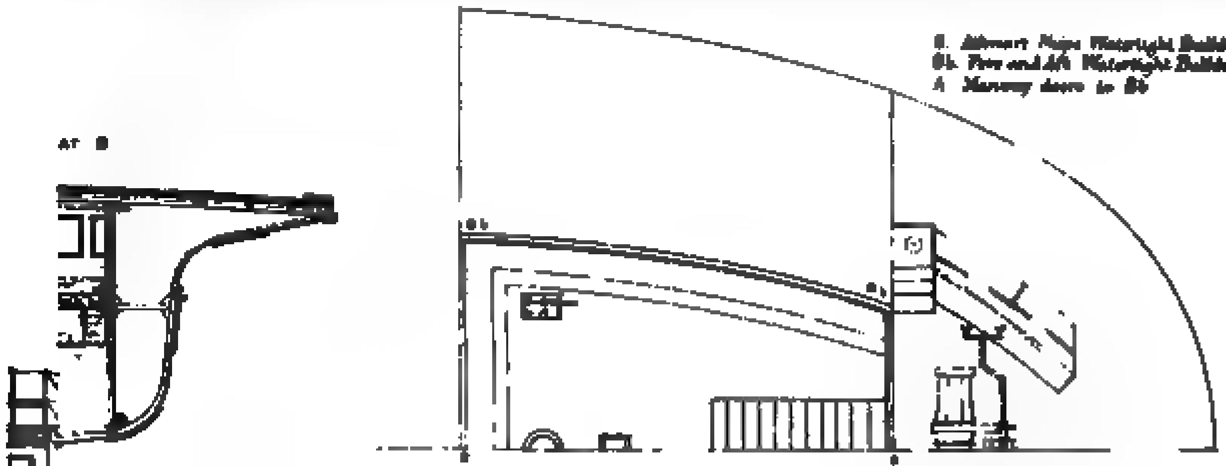
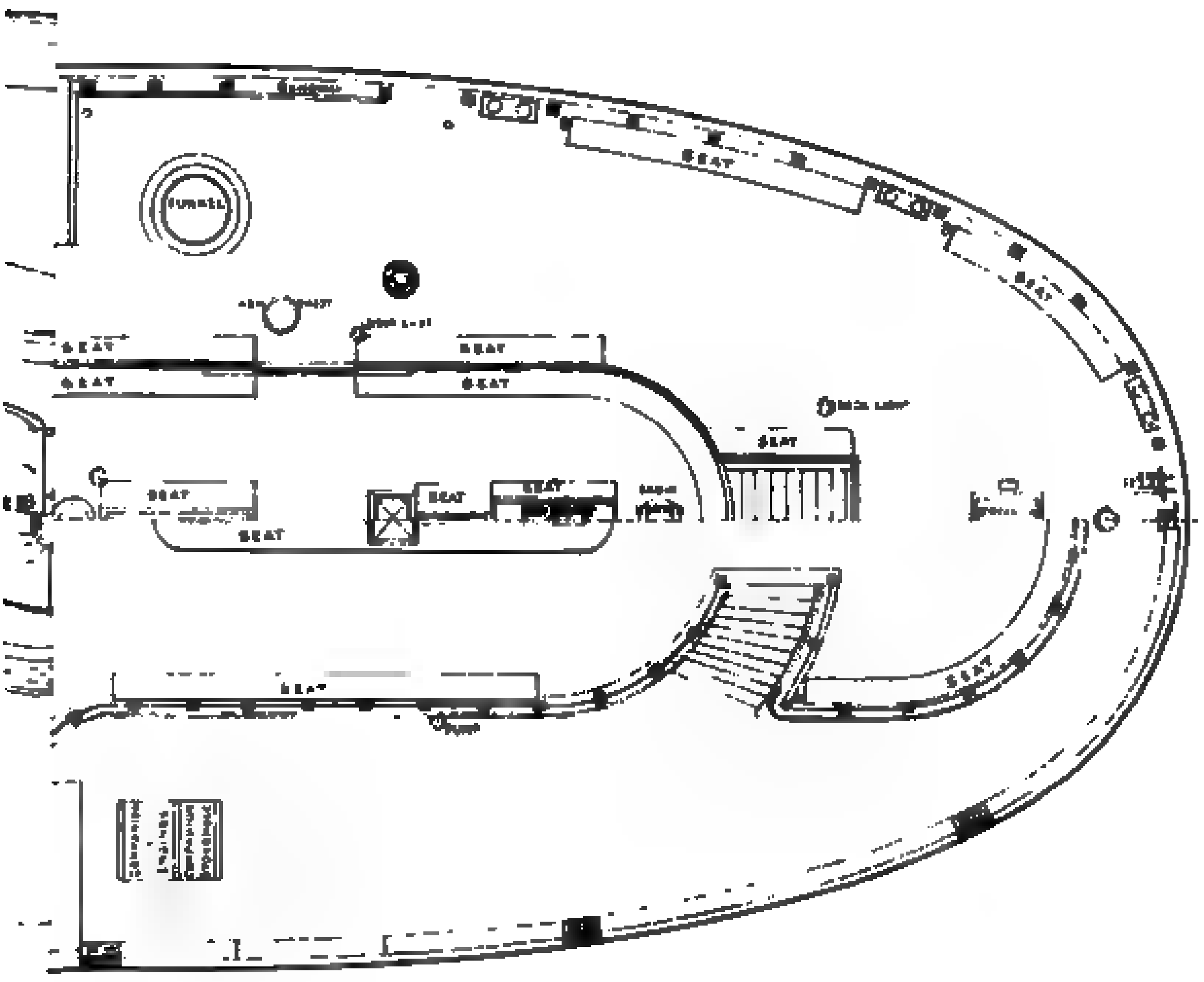


Fig. 9



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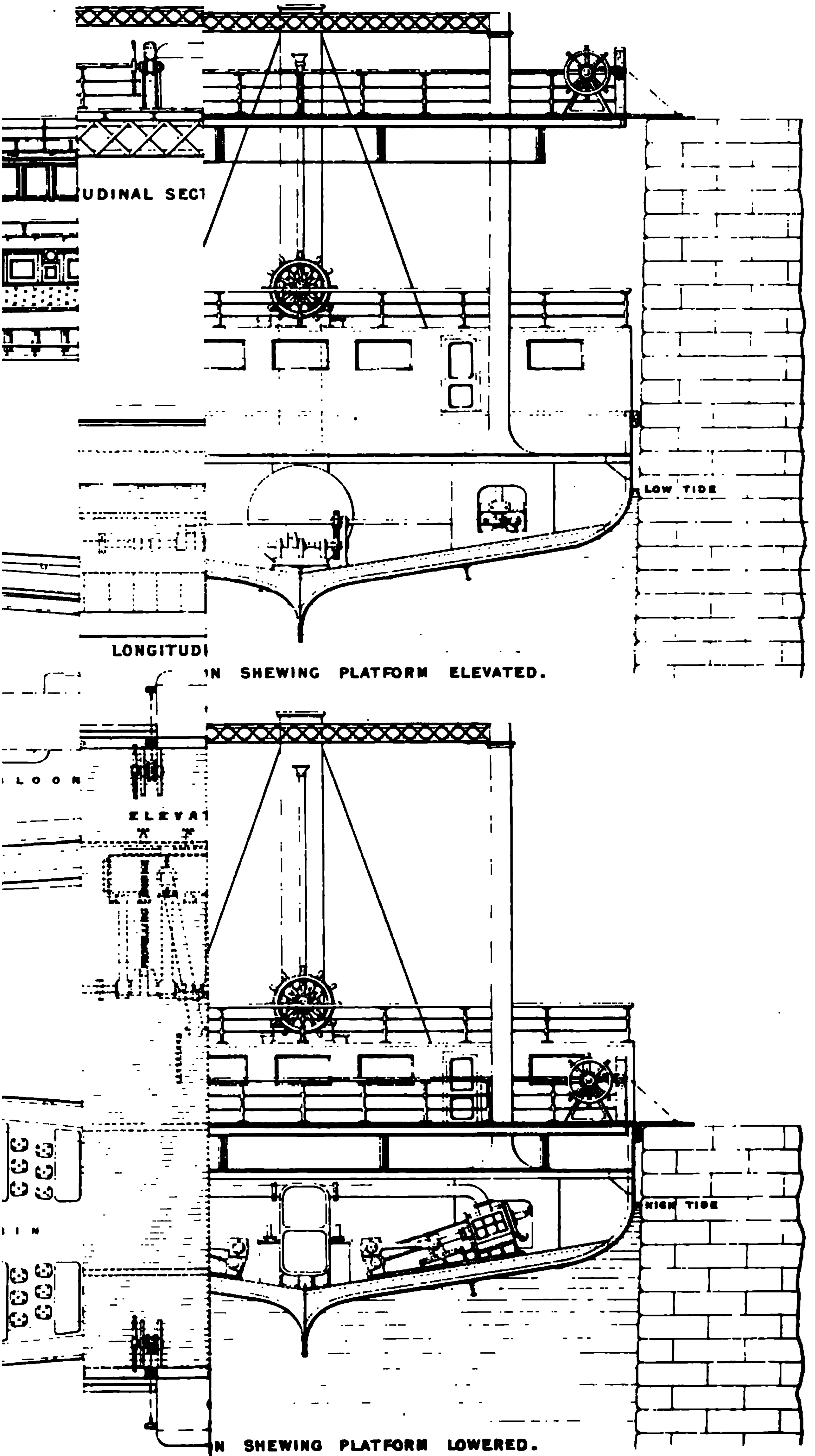
THOS KELL LITH. 4 KING ST COVENT GARDEN



THOS KELL LITH 40, KING ST COVENT GARDEN.

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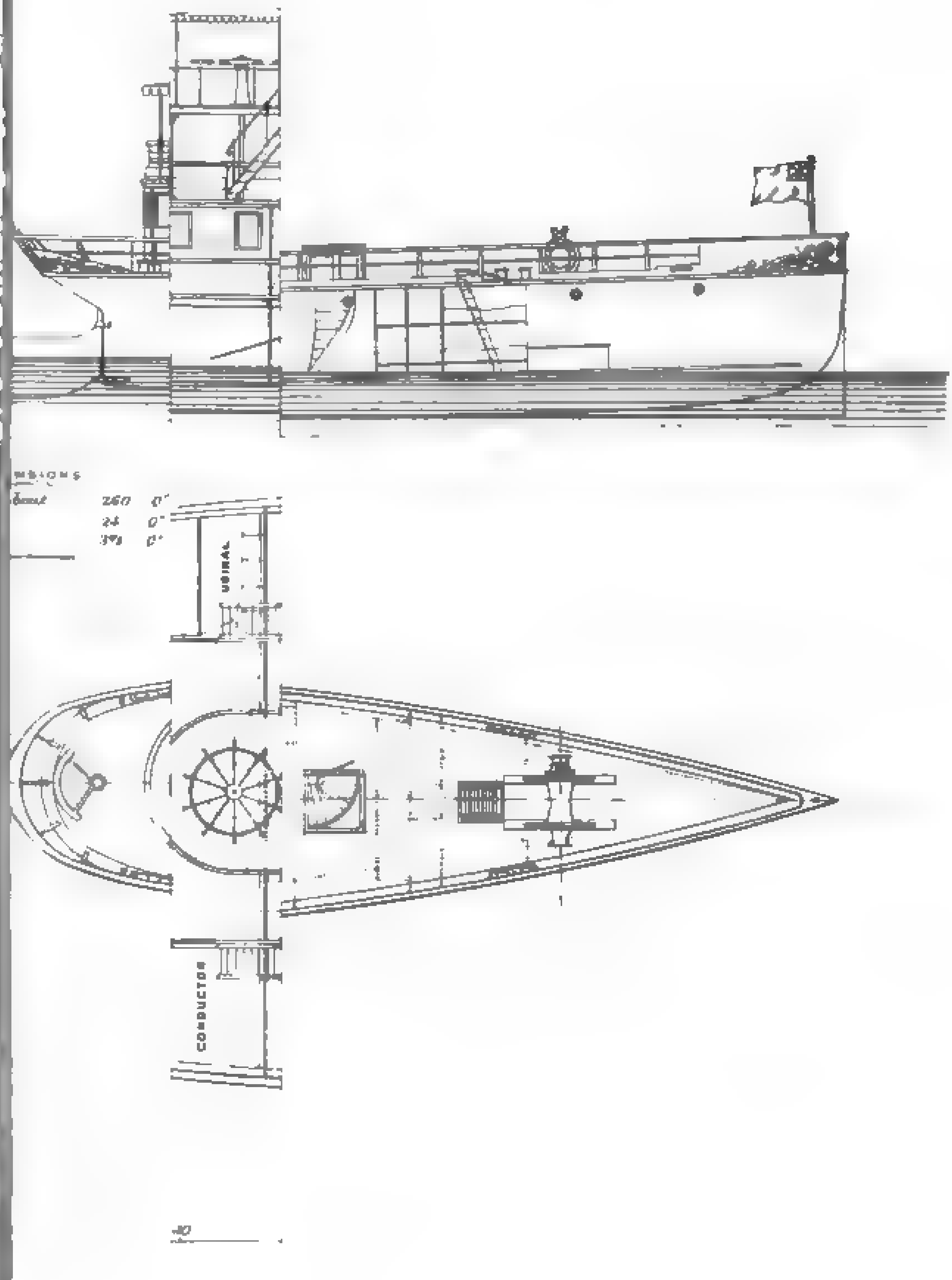

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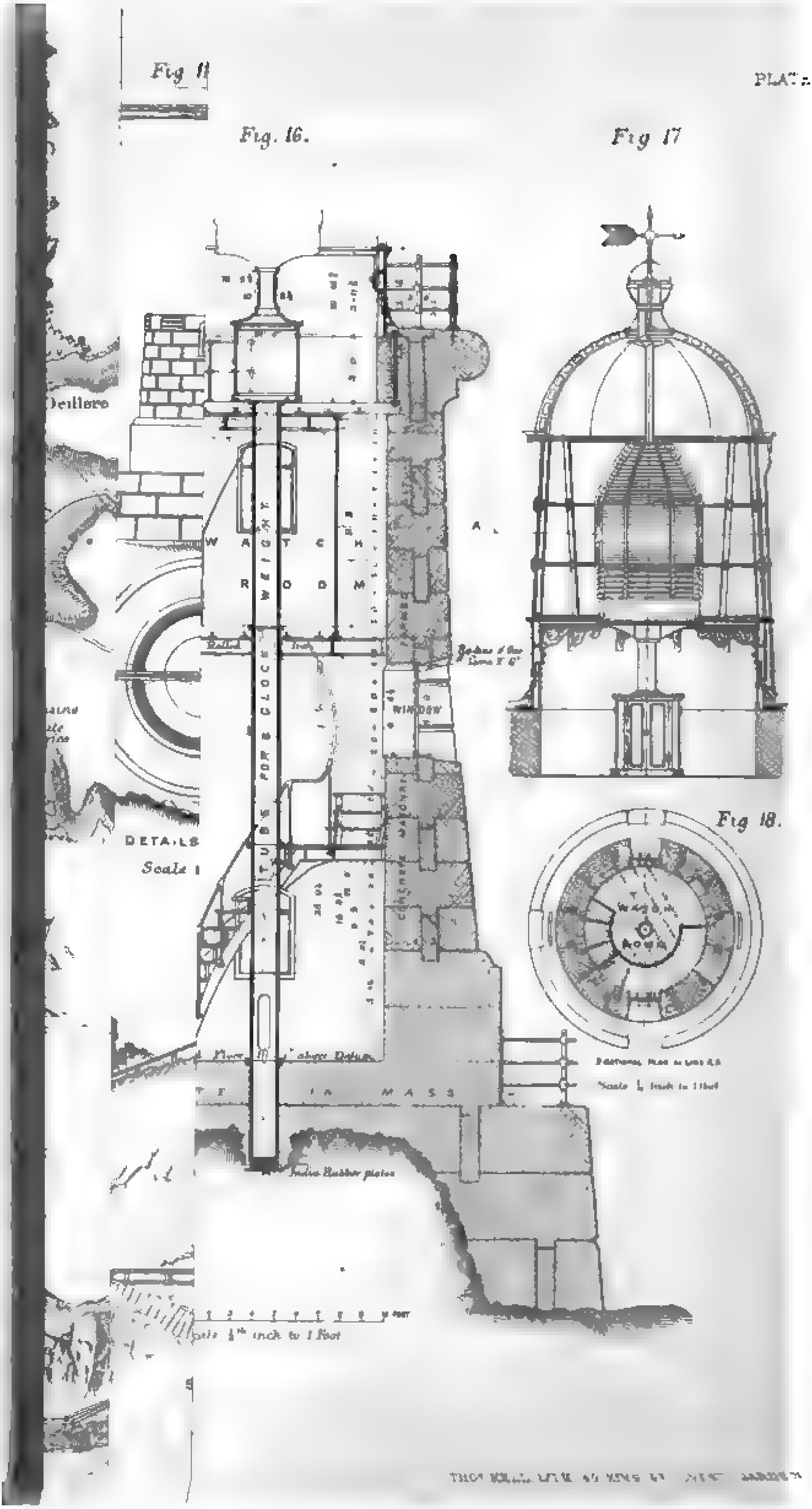
Fig 11
Fig. 16.
Fig 17
Fig 18.
WATCH ROOM
TUBE FOR CLOCK WEIGHT
WINDOW
DETAILS
Scale
India Rubber plates
Scale 1/4th inch to 1 Foot

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PLATE 10

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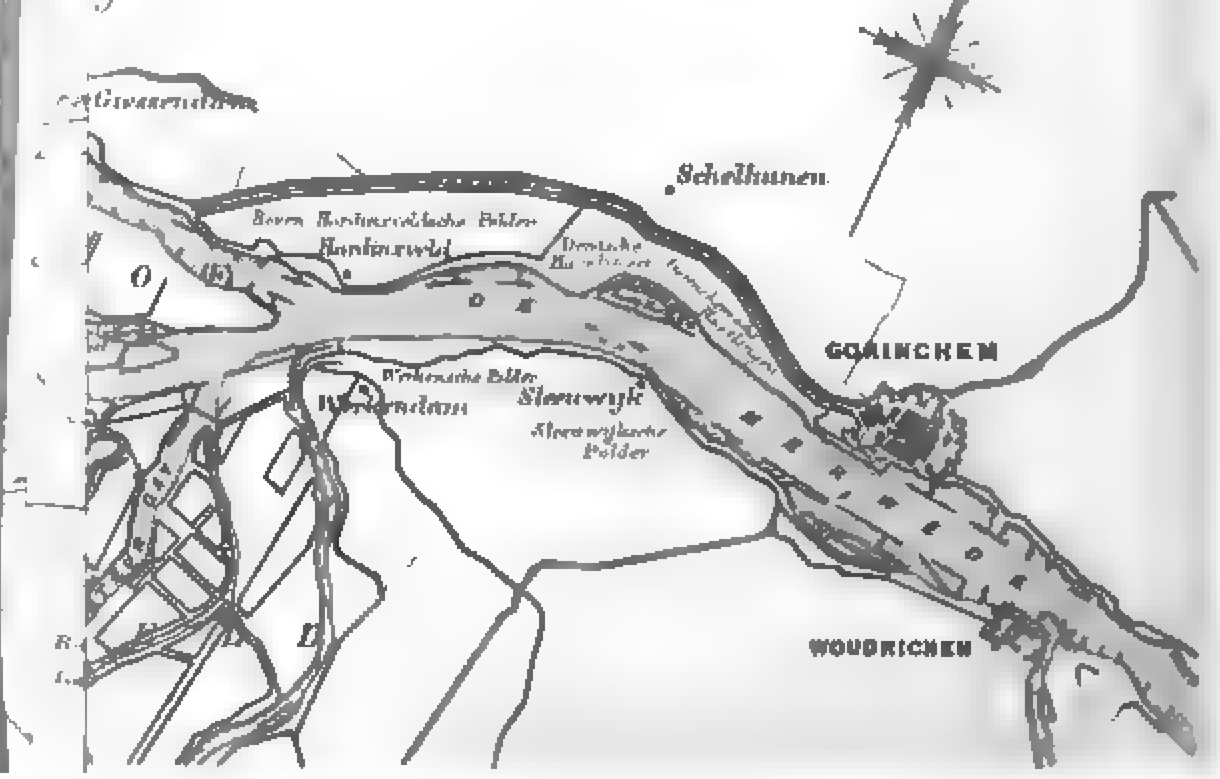

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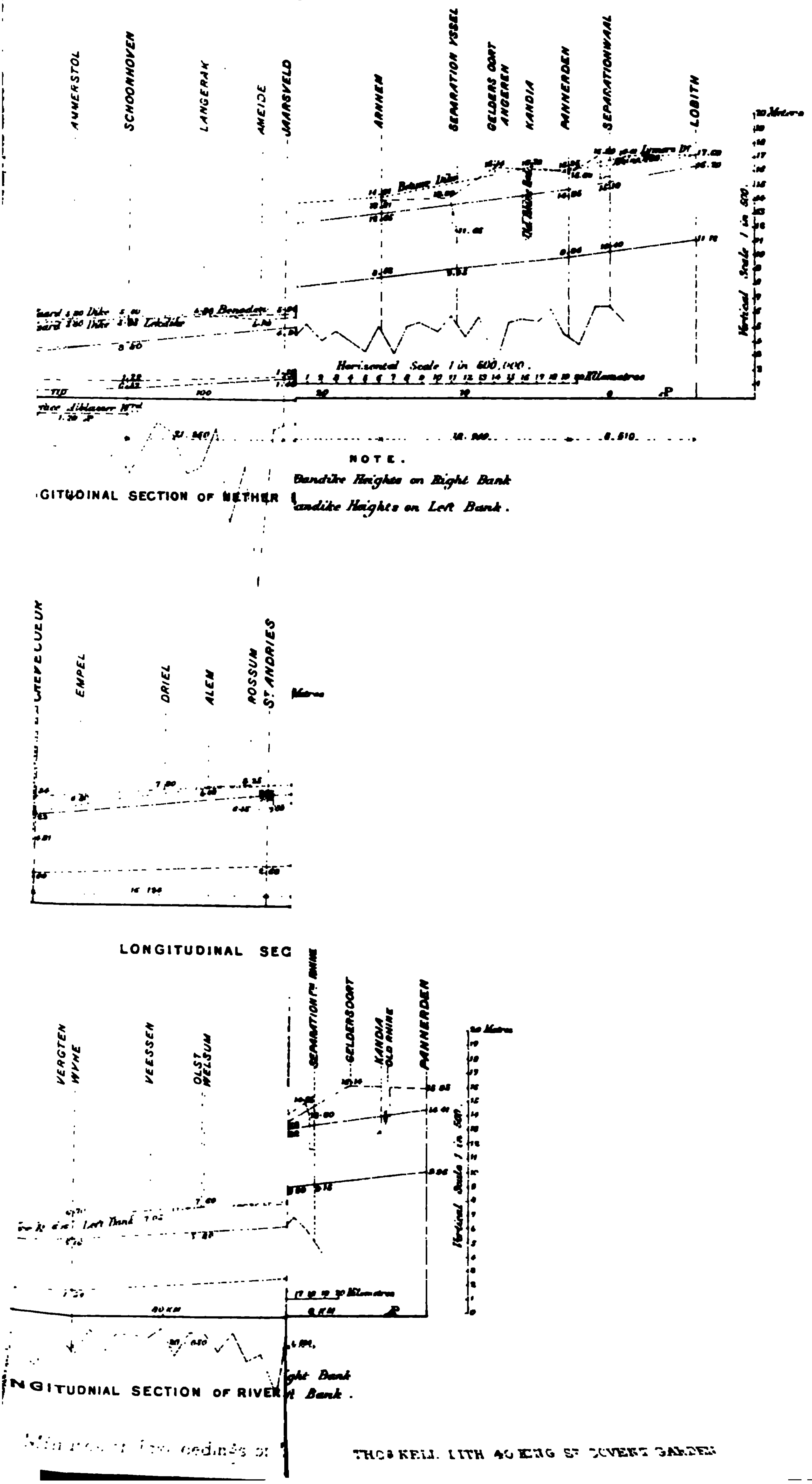
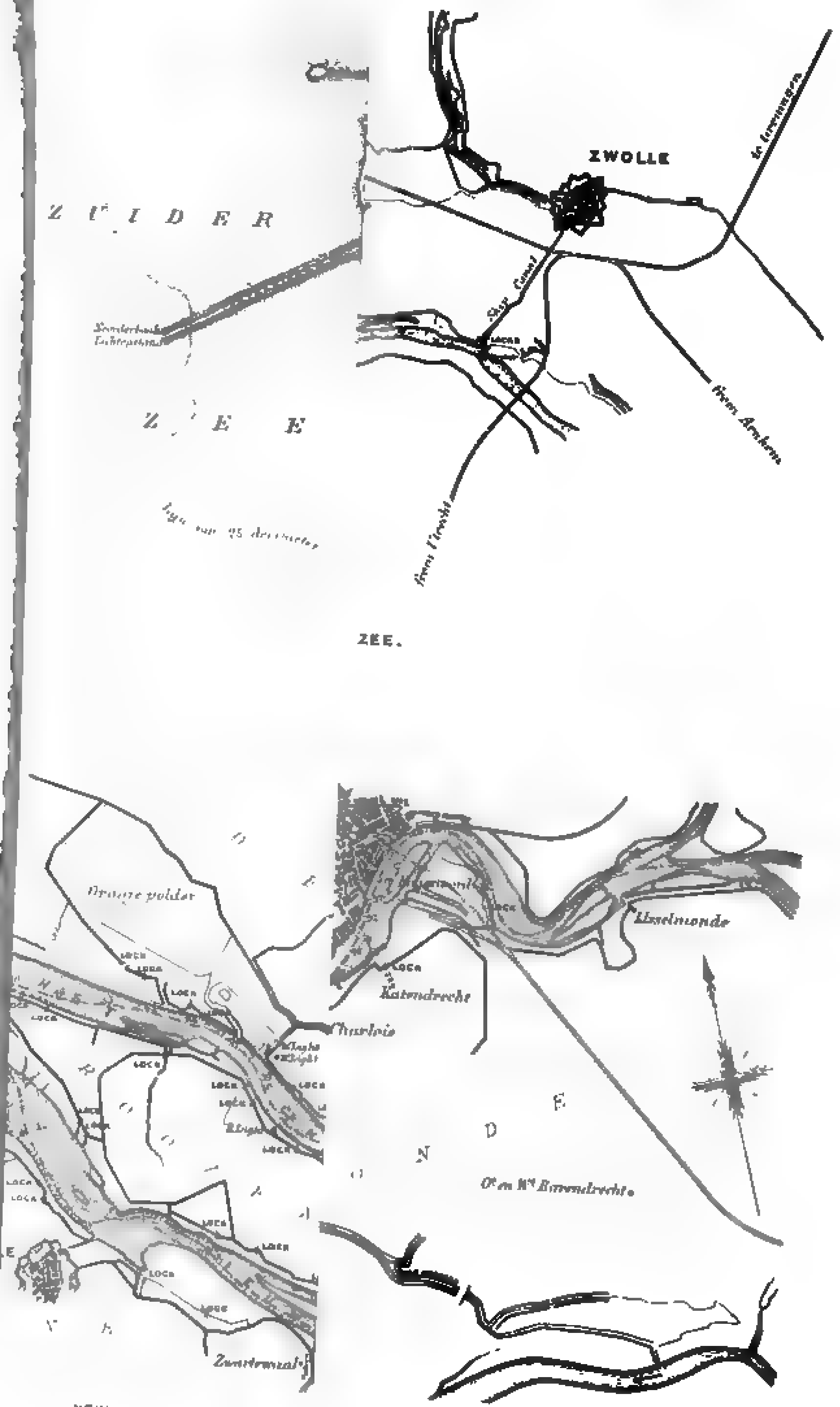


THOS KELL LITH 40 KING ST COVENT GARDEN

PLATE 12.



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THOˢ KELL LITH 40 KING ST COVENT GARDEN

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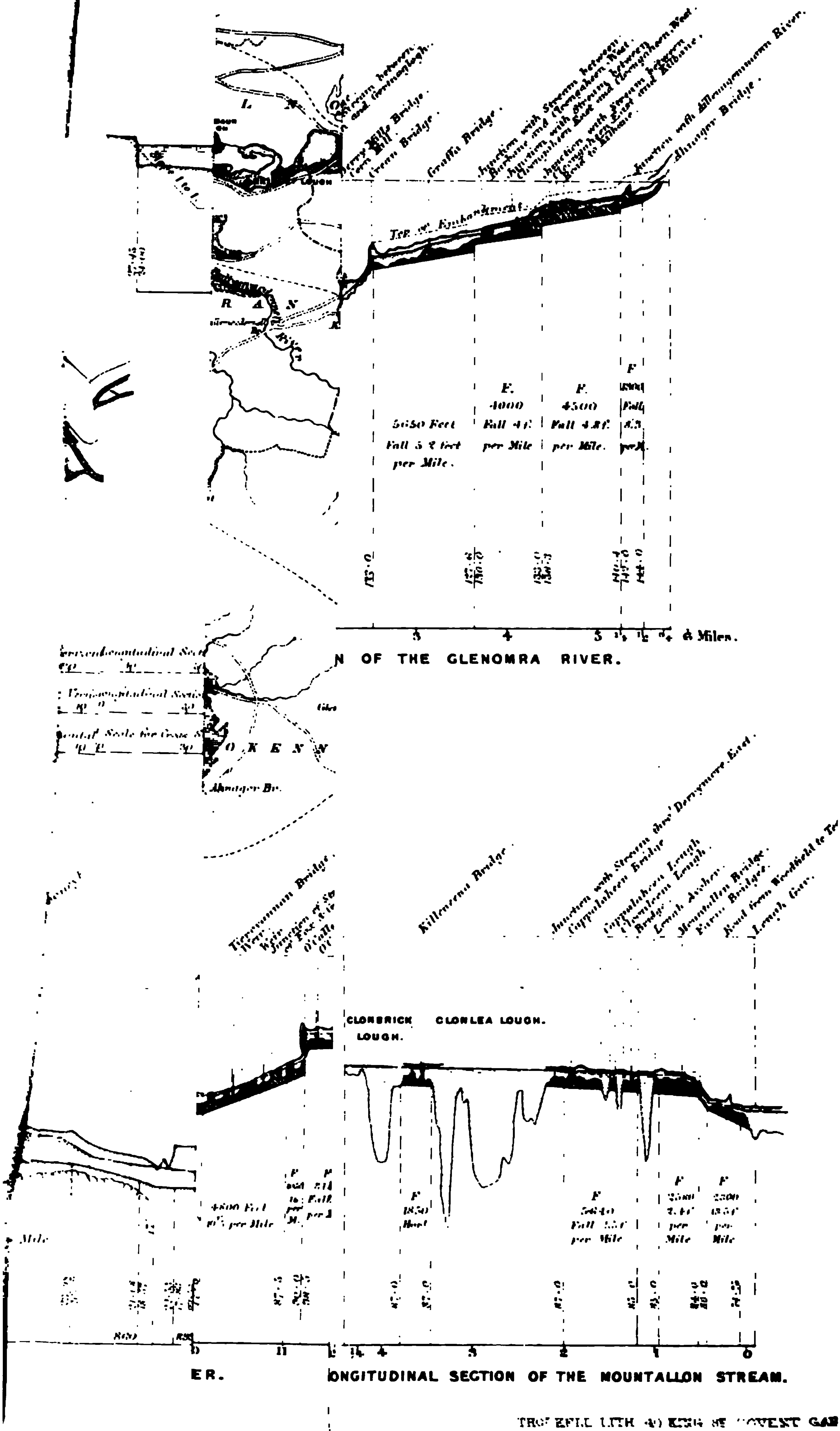

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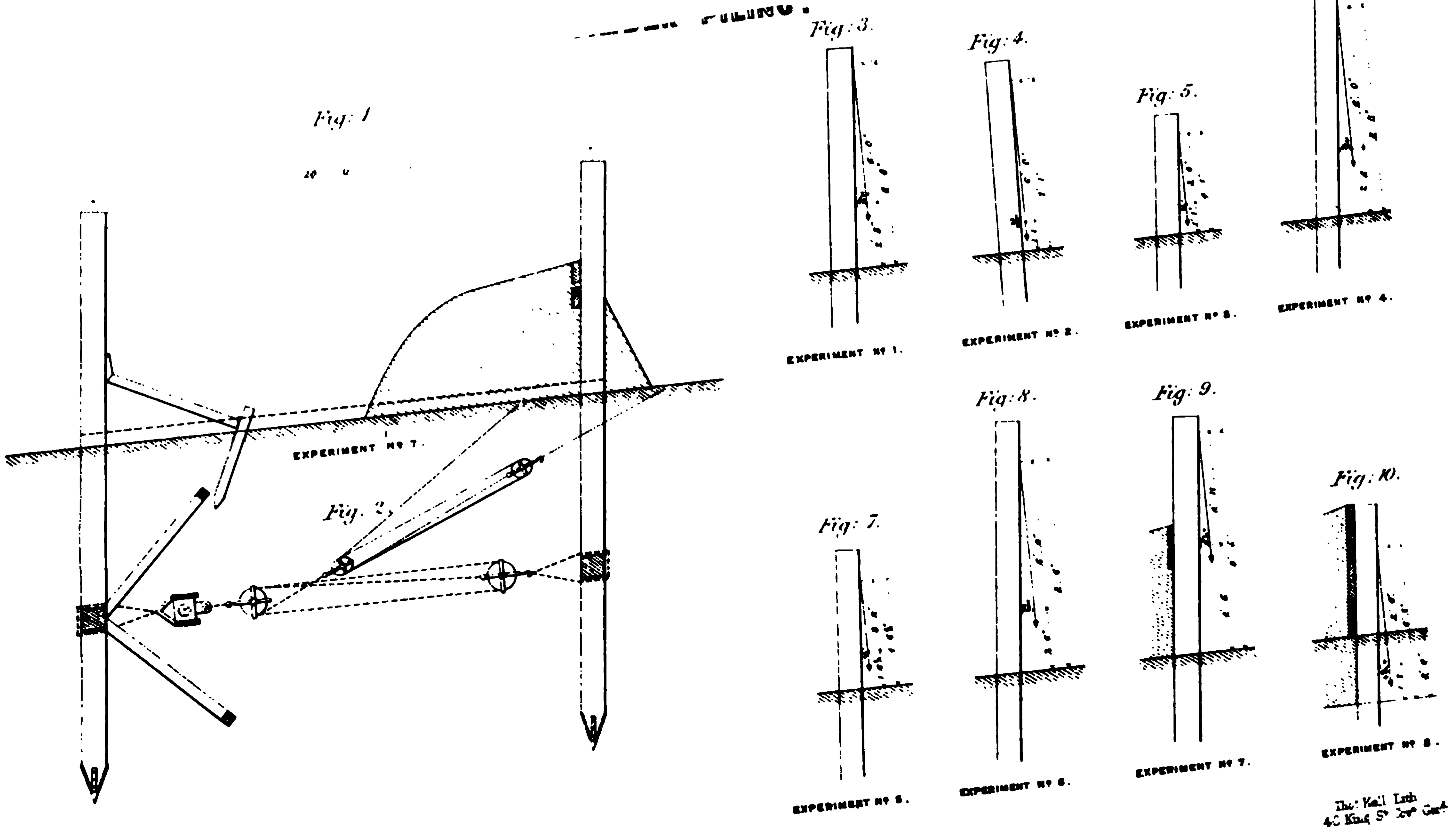
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